BELCHER'S
NAUTICAL
SURVEYOR


FURTH FORTUNE AND FILL THE FETTERS
John Murray Aynsley.

A TREATISE

ON

NAUTICAL SURVEYING:

CONTAINING AN OUTLINE OF

THE DUTIES OF THE NAVAL SURVEYOR:

WITH CASES APPLIED TO

NAVAL EVOLUTIONS AND MISCELLANEOUS RULES AND TABLES

USEFUL TO THE SEAMAN OR TRAVELLER.

BY

COMMANDER EDWARD BELCHER.

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ERRATA.

Page 16, example, *for* 1.7.20, *read* 17$^{m.}$ 20$^{s.}$
30, line 24, *for* if 12$^{h.}$, *read* the 12$^{h.}$
32, line 2, in sun's alt. *for* 31″, *read* 30″; *dele* app. above Dip.
35, in half sum, *read* 9.610871.
36, line 6, *for* gradation *read* graduation.
37, upper line, *for* 44°, *read* 34°.
38, line 13 from bottom, *for* at, *read* as; *for* cups, *read* cap, at bottom.
42, *for* heights 1315.5, *read* 1313.5, and mean 1310.3, *read* 1309.0.
44, in column for elevation make same corrections, and bottom *for* 10.3, *read* 9.0.
55, in 2nd column of boats, *for* 1st cutter, *read* 2nd cutter.
56, *for* 1 cut. 5.20.35, *read* 52° 0′ 35″.
70, line 17, *for* diff. 30,5, *read* 30.59.
91, line 1, *for* △, &c. *read* △ and S. object, &c.
99, line 14, *for* now, *read* more.
145, line 6, *for* of, *read* if.
148, bottom line but one read half a point.
168, line 22, end of, *for* north-west, *read* north-east.
187, line 21, *for* crews alone, *read* with crews alone.
194, line 14 from bottom, *for* 63.320, *read* 63320 lbs.
195, line 5, *for* log. 2.053462, *read* 2.053452, and last log. *for* 3.351032 *read* 3.051032.
217, line 1, end of, *for* height, *read* latitude.
238, bottom, *for* add ϕ, &c. *read* add ϕ— 35°. 56′. 5″.

ABBREVIATIONS, ADOPTED IN THE CHARTS.

b	*blue*		*Current*
bk	*black*		*Flood* } during Ordinary Springs
br	*brown*		*Ebb* } during Ordinary Springs
brk	*broken*	*kn*	*Knots*
c	*coarse*		*Inside of this line less than 1 fath^m.*
ch	*chalk*		*d^o.* 2
cl	*clay*		*d^o.* 3
crl	*coral*		*d^o.* 4 &c.
d	*dark*		*d^o.* 10
f	*fine*		*d^o.* 20 &c.
g	*gravel*		*d^o.* 100
gn	*green*		*d^o.* 200 &c.
gy	*grey*		*Rock with 1 fathom*
grd	*ground*		*Rock nearly awash*
h	*hard*		*Sand that dries* } The figures shew the depths on the bank at H.W. Ordinary Springs
m	*mud*		*Mud that dries* } The figures shew the depths on the bank at H.W. Ordinary Springs
oz	*ooze*		*Anchorage for large vessels*
oy	*oysters*		*d^o.* *small vessels*
p	*pale*		*d^o.* *Coasters*
r	*rocky*	H.W.	*High Water*
rd	*red*	L.W.	*Low Water*
rot	*rotten*	F.&C.	*Full & Change*
s	*sand*		*Sandy beach*
sf	*soft*		*Gravelly beach*
sh	*shells*		*Stony beach*
sm	*small*		
sp	*speckled*	F.I.R. (*near a Lighthouse*)	*Fixed, Intermitting, Revolving*
st	*stones*	B.C.R.W. (*near a Buoy*)	*Black, Chequered, Red, White*
stf	*stiff*	*fm*	*Fathoms*
w	*white*	*ft*	*Feet*
wd	*weeds*	*Spr*	*Springs*
y	*yellow*	*Np*	*Neaps*

at low water ordinary springs.

Over a figure denotes no bottom at that depth.

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NAUTICAL SURVEYING.

In offering to the public a Treatise on Nautical Surveying, I am aware that I am placing myself on very conspicuous ground; yet as others far more competent have not thought fit to come forward, I deem it my duty to offer the results of my personal experience; more particularly as the modes of operation, pursued during the surveys on which I have been employed, have been founded on a system of my own, and, I trust, have combined accuracy and despatch.

Owing to the want of some specific work on this subject, surveyors have for the most part each pursued a different method, and no one appears to have considered his own system of sufficient importance to warrant its publication. This reserve on the part of our most active surveyors has prevented the diffusion even of the elementary parts of the science, and the subject has never been sufficiently introduced into the epitomes of navigation and nautical astronomy, although it forms one of the requisites and most important parts of the education of a naval officer.

The pursuit of nautical surveying ensures to the profession a more intimate acquaintance with the higher branches of astronomy, for if an officer have a taste for surveying, the common astronomical determinations must become familiar; whereas, on the other hand, the knowledge of a youth educated to the highest pitch of mere nautical astronomy frequently ceases on the attainment of his college certificate.

The higher branches of trigonometrical surveying, or geodesic operations, have been fully discussed by others, whilst the details of a marine survey have been but slightly alluded to.

The object of this Treatise is to present in a concise form the various formulæ used in modern surveying,—the prosecution of the several parts of each survey in detail,—rules and tables useful to the seaman or traveller,—the application of the principles of surveying to evolutionary operations, together with remarks on the methods of taking observations as applied to nautical astronomy. In short, to furnish a general outline of the various points which should occupy the attention of every officer, and particularly those who may think of offering themselves for the surveying department.

So far as the subject will admit, simplicity has been aimed at; but it is needless to imagine that such a pursuit as nautical surveying can form a part of elementary education, inasmuch as it can only be attained through an intimate acquaintance with geometry; it follows, therefore, that this Treatise is calculated for those only who have completed the initiatory course of navigation.

When we take into consideration the loose manner in which charts were formerly constructed, and that many of doubtful authority are still in use; further, that officers in command ought to be qualified to apply a test of their value: moreover, that it is on the credit of such documents that the safety of our mariners nightly depends; it becomes of importance to the country and the profession, that persons qualified to enter upon a scientific investigation of such subjects should be found in every ship; and that a knowledge of surveying should form a more prominent feature in nautical education. It would materially assist officers in determining the errors of charts, and in adding the lines of soundings, if the surveyor's original marks, denoting the positions of peaks, or peculiar objects, were to be inserted in the engraved charts, and would, at the same time, enable officers, when passing known landmarks, to test their chronometers.

Officers are, by the naval instructions, required to furnish "remarks on places visited, meridian distances, *correctness of the charts*, and to *cause surveys to be made*, &c." To what extent is this practised? Indeed, it is to be feared that few of such reports are individually available; for even to a surveyor, the plotting of the work of his own assistant is often difficult. Some arrangement might be adopted in order to insure the value of such data, and distinct formulæ be prescribed in which they ought

to be furnished, of which I shall hereafter treat. Those only who have puzzled their brains over such documents can possibly understand the feeling.

Before attempting to treat on the methods adopted in surveying, it will be advisable to describe the instruments usually employed, the most approved method of observation, their liabilities to error, correction of the same, and what is more important in many cases, the means to be adopted to remedy their *absence*.

Many are deterred from pursuing the study of surveying from an idea that it is impossible to do so without a suite of expensive instruments. First-rate surveys, indeed, require great patience, *perseverance,* accuracy of eye, both in observing and reading off, neutralizing errors; and not the least important, selection of the principal stations at which such observations are to be made,—first-rate instruments are indeed to such persons invaluable. But the expert surveyor can do his work with very common tools.

Hitherto it has been the custom of the service, although it has produced many excellent surveyors, to class the azimuth compass amongst the principal surveying instruments, and more particularly amongst masters, to whom generally this duty has been assigned. But in reality, in the *genuine* work of a survey it is of no importance.

The sextant performs every requisite, and with it alone many of the most accurate surveys have been made. The compass points out the magnetic meridian, or the variation between it and the *true* as connected with the navigation *by the chart*, but should never be trusted where the sextant can do its duty; and in close surveys never enters the field.

I shall therefore commence with those instruments which the custom of the service requires every officer to provide; at the same time I would observe, that it would be very advantageous if every captain were to be supplied, in addition to the chronometer, with a four-inch theodolite and protractor, which would enable any of his officers to improve themselves in this branch.

First. The sextant (or, which I prefer, the quintant, as enabling the observer to measure thirty degrees more) is, I am happy to say, in the possession of most young men capable of observing, but from being merely *required* for the " noon observation," is not yet that important companion to a young officer which, with but little encouragement, it should be. A chronometer is now supplied to every ship. Every officer who has passed since 1815 is supposed to be

qualified to determine its rate, the longitude by it, work out the lunar distances, &c.; and why does he not? Let him but once take an interest in the chronometer, and the lunar distances will soon be in demand to prove its error and rate. He makes the land—his interest is instantly excited to ascertain how near *his* rate is to the truth, and how his reckoning stands. What have our writers on navigation been about to have omitted to excite their readers? Instantly, in ships employed in surveying, the sextant is in request; even the pleasures of the table are forgotten. In olden (and even the present) times the azimuth compass is called for. But not so with the surveyor. Is the sun visible? is the first question; if so, determine the position by chronometer, by the *true astronomical* bearing of some defined object, and take horizontal angles, if objects are to be had, to it. The true position of the ship may thus be obtained, and the truth of the chronometer tested. The difference between the magnetic bearing and that astronomically determined, will thus afford the variation on that course (if Barlow's plate be not used, which will be presently noticed.) The altitude, particularly if it be high land, should not be omitted, which, if its elevation be known, affords another test, further amusement, and incites even an ordinary mind to further deeds. Views of the land, from its *earliest outline*, through its several changes, should not be omitted. All this is part of a surveyor's duty, and yet the *sextant* is his principal instrument.

Astronomical pursuits, surveying, &c. have a peculiar attraction. Let but one moderate draught be taken, fairly tasted, a species of intoxication follows, "a scientific mania" ensues. Example only is wanting, and if that happen to be the principal, (captain or lieutenant,) the contagion rapidly spreads,—it becomes the fashion.

I have thus far treated on the sextant as applied to astronomical observations. Its value in surveying operations consists in measuring horizontal (and vertical) angles, and therefore it must be understood, in the first instance, to apply principally to such surveys as are to be conducted on the sea level, where the theodolite is not to be had, or cannot be used (being solely for terrestrial operations.)

On the same principle as the sun or other heavenly body is brought to the horizon, or the angle measured between any of them, any object, at the sea level, or nearly so, may be used. Thus, if three boats be securely moored in any triangle with their foremasts stepped, and the observers in each, placing themselves at the mast, accurately measure the angles between each, the three angles will be found to

amount to 180 degrees; and if this be carefully performed, the probabilities are in favour of the sextant performing this operation more truly than a common theodolite, under exactly similar circumstances on shore; as one minute error in a sextant angle is much more evident than by a theodolite, the wire of which may be more than this in error from the very loose manner in which the telescope is attached, or even the finger inadvertently laid on it to steady it. The young surveyor should frequently practise himself measuring the angular distances between all the objects within the horizon, and ascertaining if the sum of the principal amount to 360 degrees. If this be the case, it is to be presumed that his observations are correct.

In performing this operation grasp the sextant by its handle with the four fingers of the right-hand, and the thumb over the barrel of the adjusting screw of the telescope, so that the milled part rests on the muscle within the thumb joint. The sextant thus secured may almost be said to lie in hand. Place the second and third fingers of the left-hand firmly *beyond* the tangent screw against the limb and its support; (the index-bar having been previously advanced to bring the objects nearly in contact, allowing space to *advance* in preference;) this leaves the thumb and fore-finger at liberty for the tangent screw. The elbows almost in a line with the shoulders, (they will almost mechanically follow the plane of the sextant.) The sextant thus becomes steadied on four points.

This method has the following advantages afloat:—the body is free, moving from the hips, which in boats, remedies the motion. The instrument is more at command, particularly if the telescope be in use, as the right thumb will then adjust its position, without interfering with the observation—and by placing the left-hand as I have described, a *bad practice* is *obviated*, viz. that of arching the thumb and finger over the tangent screw, and using the fore-finger *only* on the screw; thus bearing on one side of the milled head, and materially *bending* the index-bar. The back motion is also awkward.

Where the observations are taken from a ship at anchor or on shore the elbow may be rested, particularly where the objects are so indistinct as to strain the eye. On shore I am partial to leaning on the chest with both elbows supported on the rock, or sitting with the right elbow on the right knee; particularly in this latter position, when using the artificial horizon. In bringing the objects in contact they should be crossed over each other above and below, taking the

least angle measured. This is material in large angles, and errors will frequently arise from not taking the precaution of keeping the sextant directly in the plane of the objects. In measuring the altitudes of mountains not exceeding five degrees, it is advisable to use both the arc on, and arc of excess, as by this means the index error is obviated.

The most difficult operation in surveying with sextant is when the stations are much elevated—or the objects from sea much above the observer's level. Here then the theodolite meets all objections. But it is not present, cannot be had; what is to be done? The case is not hopeless. From the sea the angle can be corrected. In the other case necessity proved the mother of invention, when just on the point of giving up.

A round of angles was required from a hill about 1500 feet above the level, a pocket sextant being the only instrument. Having a ball of twine, and having cut sticks from the adjoining shrubs, two tripods were constructed, and, suspended from each, a heavy stone afforded a fair plumb-line. These lines were brought to intersect the objects by moving the head until the exact centre for the radii was obtained. Keeping the head well steadied the angle was measured between the plumb-lines. Subsequently these angles were tested by theodolite and found correct. As the images of the lines coincided, the proof of the horizontal angle was complete.

The test of this may very simply be attained in a room where the lines of two window blinds may be steadied to a chair. If the sextant be directed to the objects above or beneath the horizontal plane they will not coincide, and it is evident that inclination from the plane acts as a radius between the objects.

More had been said respecting the sextant when the work of Simms on Mathematical Instruments made its appearance, which of course treats more fully on the minutiæ of construction, and precludes the necessity of remark on that point; but as the practical observer will not find the determination of index error and modes of observation meet all that is required, we shall proceed with our observations on the practical use of this highly important instrument.

To determine the index error, the mode usually adopted at sea is by measuring the sun's diameter on and off the arc, or on the arc, and on the arc of excess. In nine cases out of ten this is improperly done. It is the *horizontal* diameter of the sun which is to be measured, and minute observation has proved that it even varies in

the length of the tangent screw, and differs *materially* in the progressive or retrograde motion. This was first fairly brought into notice by Mr. Murdoch Mackenzie, 1774, and subsequently, by Mr. Kerigan in his admirable Treatise on Navigation. Good sextants range to about 5° on the arc of excess, and in motion on the tangent screw. For all common purposes I would advise Mr. Kerigan's method as sufficiently correct, which is in few words. Screw the tangent screw back nearly to its extent; place the index at 1° 15′ on the arc of excess; measure the horizontal diameter by advancing the limbs to contact; note this,

Arc off . .	32.30
— on . .	31.20
	1.10
Error + .	35 on progressive.

Screw on until the opposite limbs come on, taking care not to permit the necessity of a retrograde action—note this (arc on.) If the measures are equal there is no error on the progressive motion; if there is a difference, half this is the error, + if arc of excess is greatest, or — if contrary. Screw the tangent screw up, and place the index at 1° 15′ on the arc, and pursue the same method on the retrograde motion; the difference will be the error on the retrograde motion — under the same law as before, viz. + if the arc off be greater, and — if otherwise.

A preferable method, and which remedies the errors of *observation* which I believe to be *most material*, is as follows:—screw the tangent screw back, and place the vernier at 0.36′ on the arc of excess; advance to contact, note it, (arc off;) unclamp, and place it again at 0.35′ off, and proceed as before, repeating this on the whole length of the screw, or obtain five of each. Pursue the reverse operation on the retrograde movement. The results will stand as under:

Advance: off	31.10	On 31.30	Retrograde: on	31.10	Off 31.30
	31.20	31.20		31.20	31.40
	31. 0	31.40		31.30	31.10
	31.20	31.10		31.10	31.20
	31.10	31.30		31.30	31.10
	60	130		100	110
	31.12	31.26		31.20	31.22
		31.12			31.20
		14			2
Error on Advance		—7	Error on Retrograde		+ 2″

Thus two errors are obtained, one for advance and the other retrograde, to be applied in all delicate observations, and the mean for common purposes.* On shore the most perfect method is by measuring the sun's diameter in the artificial horizon under the same system as above, reversing the roof to free it from any error arising from the imperfection of the glasses. Yet, after all that has been said and written on this subject, more depends on the observer than the splitting hairs on 5″ of error; ten minutes' exposure to a hot sun will speedily change the error *more* than the point in dispute. It is yet material in close observation; as an instance before us, the error on advance is -0.35, retrograde $+0.18$. In lunar distances, where both motions are concerned, this is evidently too much to be overlooked.

Enough, it may be thought, has been said on this subject, but there is yet a very common error unnoticed, and this is in the shades, in some cases amounting to more than 1′. The error should be determined on each of the glasses and their combinations. This error is easily detected. Bring the sun's limbs in contact, shift the shades; if the images remain as before, they are correct.

Of the artificial horizon I have but few observations to make. That which inexperienced observers are at a loss about, has principally been the dross on the surface of the mercury, and they have taxed their friends with sending that of inferior quality. Mercury speedily tarnishes, and motion considerably increases its oxidation, therefore the purest may be covered with oxide shortly after straining. As this dross must always float on its surface, the pure bright mercury may be easily drawn off. Place the finger over the orifice of the bottle, and give it a shake in an inverted position, holding it over its trough, previously *cleaned*. Ease the finger and allow the mercury to flow gently, *keeping the bottle inverted*, and taking care to stop the opening before the last portion with the *dross* flows. This will produce a clear brilliant surface—which the keen observer will appreciate. In placing the roof, observe if there be two suns—one less bright than the other; if so, by slightly altering the inclination of the roof the false sun may be thrown out of the way, or above the true, and thus obviate mistake.† In placing yourself, sit so that your knees may steady both elbows. Bring the sun to the image in the horizon without the telescope, then screw it in and obtain your *focus*,

* It not unfrequently occurs that one error is $+$, and the other $-$.

† I have seen the false sun observed by mistake.

which you will find *differ* slightly to that used for other observations. Observe the colours of the two images, and bring them to nearly equal brightness by the adjusting screw of the telescope. If the sun be brilliant and the sky clear, it is advisable, in taking sights, to take them to every ten minutes *on the arc.* You get into a method of valuing your observations by the intervals, and are always prepared to make use of them with more facility for equal altitudes, on which we will observe hereafter.

In observing with the artificial horizon it has been proposed to use the coloured shades to the telescope. This may sound very proper, but the practical observer is aware that he frequently cannot shift his shades sufficiently fast to save his observations. If, then, the true errors on the glasses are attained, the observer knows from practice afloat with the same glasses how far all his observations are to be classed; and to a person who has no favourite instrument, and is constantly playing with half-a-dozen, it is impossible he can refer to his determinations with that confidence he ought. If a multiplicity of instruments are used, the numbers attached to them should head the observations, thus infinitely multiplying his labours.

Many observers prefer taking their own time, and frequently keep the watch in their left-hand. Observers are not generally acquainted with the facility with which a watch may be made to *gallop two or three seconds at a time!* by a slight motion of the hand, and as easily *stopped.* This was very kindly communicated and illustrated by Mr. Barraud, and is frequently practised in setting watches. Therefore the observer who thus makes use of his watch need not feel surprised at material changes from the times of comparison with his chronometer. The very action of the tangent screw would effect this, if the watch be in the left-hand. With respect to the adjustments of the sextant, it is to be observed, that unless the error be material, it is preferable to disturb the screws as little as possible, as the glass frequently will take a bias which the straining of the screws will not obviate. The only method likely to succeed in such cases has been to reset the glass, but those who value their instruments had better leave these operations to the maker. Sextants for surveying are more convenient if the outer or unsilvered half of the horizon glass is unguarded, but those who have such sextants should take spare glasses to sea with them. The French frequently make use of metallic reflectors as the spray speedily destroys the silvering. Before taking leave of this subject it may not be unimportant to describe the ope-

ration of silvering the glasses of sextants, as those employed on surveying duties very frequently have to perform this operation.

The *requisites* are clean tinfoil and mercury—(a hare's foot is handy)—lay the tinfoil, which should exceed the surface of the glass by a quarter of an inch on each side, on a smooth surface, (the back of a book,) rub it out smooth with the finger, add a bubble of mercury about the size of a small shot, which rub gently over the tinfoil until it spreads itself and shows a silvered surface—gently add sufficient mercury to cover the leaf so that its surface is fluid. Prepare a slip of clean paper the size of the tinfoil. Take the glass in the left-hand, previously well cleaned, and the paper in the right. Brush the surface of the mercury gently to free it from dross. Lay the paper on the mercury, and the glass on it. Pressing gently on the glass withdraw the paper. Turn the glass on its face, and leave it on an inclined plane to allow the mercury to flow off, which is accelerated by laying a strip of tinfoil as a *conductor* to its lower edge. The edges may, after twelve hours' rest, be removed. In twenty-four hours give it a coat of varnish made from spirits of wine and red sealing-wax. It may be as well to practise on small bits of common glass, which will soon prove the degree of perfection to which the operator has attained.

The next point connected with our subject is the "case of instruments," or rather, such mathematical instruments as are requisite for the common purposes of surveying. We will, however, deviate from the sole connexion with surveying, to observe on the customary cases of instruments provided, and suggest an alteration.

Parents, when sending their children to sea, usually supply them with "a case of instruments," without inquiry as to their use, &c., and looking rather to economy, such as soon shares the fate of other playthings. Not that they are deemed *superfluous*,—on the contrary, (*possession* is perhaps one of the greatest inducements to become acquainted with their use,)—but it is from a feeling that they are not *sufficiently valuable*—that they are not worth repair—that another *better* set must be purchased as the party advances in life—and that when wanted, they are deficient in the necessary instruments.

They should contain the undermentioned—

A well-made pair of compasses, with pen, pencil, and elongating legs.

A well-made pair of hair dividers.

A well-made pair of plain proportionals (length of case.)

Plain scale and protractor on ivory. *(See plan.)*

Pair of parallel rulers.

Brass semicircle three inches radius. *(See plan.)*

Two good ruling steel pens.

These are sufficient for the common purposes for which they can be required at sea, and for those inclined to attempt surveying. The explanation of these will be short. The compasses are well-known to every school-boy. The proportionals are made use of in dividing a distance into any number of parts not exceeding ten, which is effected by shifting its centre, and is particularly useful in reducing plans, &c.

The plain scale should contain the inch divided into 10, 12, 20, 30, 48, and 60, (*vide* plate I,) the whole length of the box, and on its reverse the protractor.*

The protractor of brass should have its base on the *upper* part of the scale, by which it is more accurately applied to the work, and the divisions less liable to injury by a fall. The use of the protractor is to lay off angles on paper without the clumsy method by compasses with the scale of chords. Thus, suppose the angle taken by the sextant between two objects be 54° $30'$, draw a line between the right-hand object and the point from whence the angle was taken, (if such right-hand object be available, if not, *vice-versa*,) then by laying the protractor on this line read off 54° $30'$ right or left, estimating the half degree by pricking with a needle or sharp pointed pencil; draw a line through this mark, and it will be the angle required.

There is a difference in using the brass semicircle and the ivory scale protractor, which is deserving of notice. The brass protractor is constructed with its divisions on the same length of radius, and consequently all its divisions are equal. Not so on the scale; its difference being relatively one and a half at the rectangle, three at the base, and three and a half at 30°. Now it must be very apparent, that if an angle is to be measured to the greatest nicety the greatest radius should be made use of, and therefore if the angle exceeds 45°, the line from which it should be measured should be that transversely through 90°, and all angles under 45° by laying the scale with its base to the line.

* Mine measures ten inches in the clear inside the lines of division, by five in width; I have introduced twelve parallel equidistant lines, which afford a constant scale for dividing spaces within those limits, by merely drawing the diagonal over them.

This brings us to an objection to the present method of marking. Any person will instantly perceive the excess above the rectangle, but is frequently misled by the figures. It would be preferable, therefore, numbering externally from the base to 90°, and internally from 0 to 90° reverse. (*Vide* plan.) Each has his own hobby, and this only will be consulted. With respect to parallel rulers, they are seldom used for any purposes involving nicety. They are handy in small operations, but no *machinery* can be trusted over any large space. The principle of Marquoi's parallels is that which may be satisfactorily adopted, and cannot fail, if fairly managed. Place the ruler (alluding to the three-feet brass) on the direction which the triangle gives at the point of starting, and weight it. The triangle applied to any part of that line must give *true* parallels, and has this great advantage, that it may be left, and returned to, with *safety*, and in minute graduation of a meridian, &c. affords great facility, and enables the operator to rule with more firmness.

In making use of the ruling pens, bear in mind that they are set for ruling with the screw from you, and that pressure on the side on which the milled head is, closes the pen, the screw acting loosely through the hole; the pen should incline at an angle of about 45° to the right.

Lastly. A good plain drawing ruler of ebony, about two feet six inches, will be useful, but it will rarely preserve its plane when so long. Before quitting this subject, it may be as well to afford the means of proving and producing lines on charts, where no rulers sufficiently true can be obtained. Fine wire is the most perfect, but where this cannot be obtained, procure a line of silk, *wax*, and *rub* it well, strain it tightly over the points, so that it will just clear the paper, and with a fine pencil trace the points within which your ruler will extend. If you have four or five very fine needles, stick them in, and you will readily detect, by applying the eye to the surface of the paper, if they are truly placed.

In measuring bases, if the lead or other line is to be used for such purpose, it should be old, dry, and well stretched—but the cod-line is preferable. The best method is to stretch it first *quite dry* between two measured points, say fifty feet, over bolts (as in making sword mats): wet the line—when it dries observe how much it droops after sitting on the bight, and if its elasticity be still great; if so, take in the slack, and repeat the wetting. If the line bights (or droops) from its own weight after this not more than a foot, you may mark it at the

bolts, and it may serve the common purposes of surveying—but should be verified, if possible, by sound, of which hereafter. In 1824, I purchased a wove window-line of 350 feet, which I continued to make use of until August, 1833, when it was still in good preservation; and the bases measured by it against chains seldom differed materially.

The foregoing instruments include sufficient for following up marine surveying with tolerable precision, and many of our best surveys have been carried on for considerable periods without the assistance of those about to be described, and which are principally called for in land operations, and used by the principal surveyor and his assistants.

THE THEODOLITE.

Under this denomination, instruments varying in price from ten to a hundred and fifty guineas may be classed; but after their vertical motion embraces the complete circle, and they are used for astronomical purposes, they are usually denominated, azimuth and altitude, astronomical circles, &c.

In speaking, therefore, of the theodolite, we will confine ourselves to those which are portable, easily adjusted, and are not above nine inches diameter. That of four inches plate is the most convenient for common surveys. It is furnished with a tripod stand, on which it is screwed, and is then brought truly level by means of spirit levels fixed to the upper moveable plate. Before placing the instrument on its legs, see that they are in firm ground, the plate as nearly as you can judge level, and that the legs have fair spread. In screwing it on, take care that it is *home* to its shoulders, and a moderate strain of the hand on the lower or levelling plates may be exerted to ensure this. Level the upper plate without clamping the instrument above or below. That is, on its own vertical axis. Set the telescope level, and prove it by turning it in the direction of each of the levelling screws. If this hold, place the vernier at 360°, and clamp the upper plate. Direct the telescope to the object from which the angles are to commence, (which should be invariably a station from which your present position *has been taken*, or to which you are about to

proceed, as will be shown hereafter.) Tighten the lower collar clamp; the tangent screw, which gives motion to the whole instrument, and is attached to this collar clamp, is now to be used to bring the wire of the telescope to intersect your zero or primary object. Theodolites are very liable to alter shortly after levelling, and every precaution should be taken to render the observations perfect. First walk round the instrument, treading near the legs, and where you suppose your weight will rest when reading off, and observe if this influences the levels. The remedy must be obvious. Next unclamp the plate, and try if the motion in azimuth affects the levels—for frequently the clamping of the collar will disturb very excellent instruments. After correcting the errors by the levels, (if they be traced,) place the vernier again accurately at 360°, and adjust the wire to the object. The instrument may now be supposed adjusted for observation. A systematic course in observing with any instrument should be adhered to. That to be preferred with this, is by taking the object round to the right, or as the graduation is numbered. In the motion be cautious that the head does not bear against the eye-end of the telescope, and that the hand is not applied to it more than can be avoided. The motion in azimuth should be gently given, after unclamping the plate, by the finger and thumb arched over the base of the Ys, or standards for the telescope, *by both hands, (not on one side only.)* Bring the wire to the object by hand, clamp, and complete with tangent screw if requisite. After your round of ∠ s, always refer the telescope back to zero, or object from which you started, and make a *practice* of *reading it off*, and *noting* it. By this you will detect if the instrument has moved.

Some instruments are furnished with a lower telescope set to zero, which at any moment detects such error, and the person who notes the angles may conveniently ascertain it when the body of the observer does not impede.

Several errors arise which but too frequently are attributed to the motion of the plates, when truly it is the unsteadiness of the telescope in its Ys, which is only confined from above by a slight cork. Before observing, try gently by hand if the collar clamp* is secure. If this be correct, examine the clamps which confine the telescope in its Ys, as the slightest irregularity there will make a most material difference, and which will be very apparent if the finger be gently applied to the

* In my private instruments the collars are furnished with cork fillets and screws, which effectually clamp and save much strain.

telescope when the wire bisects an object. If the observer have idle time, he cannot better employ it than by *reversing* the telescope, (end for end,) and taking the principal objects again. He should satisfy himself, before he observes, that the system of wires be correct—and that the telescope moves in a truly vertical plane. The proof of the wires is very simple. Fix upon a very distinct object, and bring the wire in contact (with the level above.) Invert it, or turn it in the Ys until the level is beneath. If both observations correspond, the wires are correct; it may then be tried by reversing the telescope. The same applies to the horizontal wire. To prove the vertical motion is not so easily done. However, the simplest I shall describe. From the top window of a house suspend, clear of the wall, by a fine line or wire, as heavy a weight as it will bear, avoiding wind if possible, and immersing the weight in a bucket of water. This will be very nearly a plumb-line. Place the instrument so that it will measure the extremities, (70° being about the range of theodolites,) and direct the telescope to the *level* mark; bring the wire in contact, depress as far as it will admit, and then elevate. If the wire follows the line truly, without opening right below, and left above, or *vice versa*, the vertical motion may be considered correct.

Place the artificial horizon in a convenient position for reflecting this plumb-line, and observing it direct and reflected by the instrument, which is the neatest and most complete.

To prove the graduation, a very simple method may be practised, if the instrument be trustworthy; and where it is wished to measure very accurate angles with an azimuth transit, it is thus made a repeater. Select two objects about 35° (an odd number) asunder, make the left zero, measure to the right, read off, unclamp the collar, and by the lower tangent screw bring the telescope again to zero—measure as before, (which should be double,) and thus go through the whole circle; ten observations should be taken; the mean of these will be the true, and by subtraction the errors on the arc and between what limits, may very nearly be detected. It must be apparent that if the first measurement be correct, all the others are made under similar conditions.

In observing altitudes or depressions, the vernier should be read off when the telescope is *level*, and then the angle. *After* the round of angles is complete reverse the telescope, and repeat *vertical* ∠s. This is *very material*—more nicety should be observed in adjusting the vernier of those arcs, and greater facility in reading off. *Every*

theodolite should be furnished with coloured glasses to observe the ⊙'s azimuth, as this important observation should never be omitted. Astronomical bearings afford a means of test always satisfactory to the surveyor.

In making such observations, a beginner finds some awkwardness in the two motions. One only is necessary—that in azimuth; a watch should be used, as the time of observation, if it can be shortly compared with the chronometer, is another check. The observer is aware, of course, of ⊙'s motion. Adjust the telescope to an even division that the sun will shortly come to—note this; move the instrument in azimuth until the limb is about half a diameter distant, clamp when both the limbs are that distance from both wires, and follow the motion in azimuth with the tangent screw until the limb touches the horizontal wire; note this time, and read off; keep the same altitude on, and watch his opposite limb under the same conditions; note time, &c.

			° ′	° ′	° ′
Thus	☾ 5 V/32	10.15.10	$\overline{\odot}$ 43.20	184.20	4.30
		1.7.20	$\underline{\odot}$	186.14	6.14

By comparison with a watch whose error on apparent time is known, we have a corroboration; the ⊙'s true astronomical bearing is also deduced from his altitude, and the direction of each point thus accurately determined. N.B. The horizontal semi-diameter is to be applied to the readings in azimuth, as well as altitude, if one limb only be observed.

THE CIRCULAR PROTRACTOR.

This is one of the working instruments of a surveyor, and enables him to lay off angles to great nicety, being read off by a vernier to minutes, and being capable of extending the point of its radius about ten inches. The centre is open, with a glass with rectangular cross at centre; and four marks at right angles on the inside of its rim, enable the operator to place it truly on its position.

SIR H. DOUGLAS'S FIELD PROTRACTOR.

This is a handy field instrument, and principally made use of by the engineers. It combines the sextant and protractor, and in rapid work does not require to be read off, as the instant the angle is taken the instrument is applied to the paper and ruled off. It has a scale divided to 1760 yards.

STATION POINTER.

This instrument is principally used in laying down soundings, which under certain conditions are sufficiently accurate for any chart work. It obviates the necessity of calculating the triangles or cutting up the paper by constant projections; and when it is considered that the observations themselves are not accurately made *over the very spot*, except in *close surveys*, or where *danger* exists, it has become a very favourite instrument. It is composed of a brass circle about nine inches diameter, having one stationary radius about two feet long, the left side of which is at zero. Two other moveable legs, or radii, are furnished with verniers and clamps.

To use the instrument, lay off on the right radius the right-hand angle, and the left on the other. The nearer they approach to right angles the better. Lay the instrument over the points, and move it right or left until they are fairly intersected by the radii. It is then apparent that the centre of the circle is the situation of the observer. The instrument is furnished with a sliding, sharp-pointed pin, which is then pressed into the paper to mark the station.*

* This instrument I have materially modified, rendered more portable, and I trust much easier to handle, and the most material objection, which annoyed me by tearing my plans, *the pin*, is entirely superseded by an open brass *semicircular* centre, half-inch aperture, which enables me to use the pencil, observe where the spot is, and frequently make use of the instrument for measuring angles. In the old instrument the radii were much beneath the plane of the circle. In mine, they are merely the thickness of the brass radii, (one-tenth of an inch,) and support the circle firmly. A circular protractor of similar centre is fitted with *shifting radii* above all. When in use, the circle and radii are all in the same plane.

As a substitute for the station pointer, we may use paper, by laying off the angles on stiff writing paper, and cutting the lines through. Tracing paper performs this duty very conveniently, and in small plans is the only method ; the instruments are too large.

RAPER'S MACHINE

FOR SOUNDING IN A STRAIGHT LINE BETWEEN TWO OBJECTS.

This is a very ingenious invention by Lieutenant H. Raper, R.N., and first introduced to the public in the "United Service Magazine," p. 302, for September, 1829. The reader is referred to it for minute details; I shall, therefore, merely extract his description to the annexed plate, and add such remarks as have been the result of practice with it.

"It consists of two tubes about one and a half inches in diameter, connected by a smaller one, as shown in fig. 11, pl. III. The eye is placed at the small aperture at the end E of the longer of the two tubes, which is directed towards an object, the cross tube being held horizontally, and by turning the head slightly to the right, to enable the light to proceed from the object behind, clear of the ear and hair on the temples, the image of the reflected object is thus brought into view under that viewed directly. Motion, right or left, until they be brought in contact perpendicularly, brings the observer truly in line between the objects.

It frequently happens in sounding that the sun interferes with one of the objects, preventing its being reflected at a great angle, and as frequently that the large angle exceeds the range of the sextant. For instance, let four objects be situated as follows:—A to B $= 150^\circ$, B to C $= 30^\circ$, C to D $= 30^\circ$, D to A $= 150^\circ$, the sun being over either *b* or *d*. Now by making use of Raper's instrument we have three objects in line—A, observer, and B; therefore AC $= 180^\circ$. If one observer use the sextant, and take $bc = 30$, or $ad = 30^\circ$, or both, the station must be secure.*

* I principally made use of it on board the ship, causing several angles to be taken at the instant I called "stop," which not only verified the position of the soundings, but also afforded a test for some of the minor stations. In boat service with one observer, her way would of course be stopped at the moment the objects were in one.

In closing, for the present, further remarks on the instruments, we shall observe but shortly on the patent log, sounding machine, and watch for measuring base by sound, invented by Mr. Massey, and finally, Barlow's plate for obviating local attraction.

The general use of the Patent Log in surveying operations is of itself a proof of its value. It is composed of a brass wedge-shaped box, having within, three cogged wheels, acting on each other in such proportion that a total revolution of one completes a division of the next, (or one-twentieth,) a revolution of the next one-eighth, registering thus from 160 miles to tenths, and decimal parts; the action is by the rotation of a spindle with four spirally fixed wings, (termed the rotator, or fly,) which turns an endless screw in the box, acting directly on the decimal wheel. It is towed astern by a stout lead line of sixty fathoms, and is registered every time the course is changed, angles taken, &c., but should not be reset until the twenty-four hours have elapsed, the ship anchors, or goes less than three knots—(when it becomes uncertain from not towing horizontally.)

The patent Sounding Machine does not stand in such repute as the last.*

Burt's Buoy and Nipper is a favourite, but his buoys should be made of better material. We superseded them by duck, made on board. They are admirably adapted for ground log, as will be noticed hereafter.

Massey's Watch for measuring base by sound is a stop-watch, which divides the second into thirty parts. It would have been more complete if the motion had been firmer, and the division ten. To make use of this to advantage at least five guns should be fired, and the sum of the five intervals between flash and report divided by five. [Not set the watch afresh each time.] But I have preferred using a good watch, as the beats by those who are accustomed to such measurements, can be mentally divided with as much accuracy. Indeed

* At one time I strongly defended it on the firmest reliance on its mechanical principles. Constant practice, however, has caused me to change my mind: but I think that it is worthy of the attention of the inventor. If it is to be made use of, and *very carefully* it must, the wings should be as decidedly large as those of the log. It never can travel so fast, and therefore ought to be larger. I tried some experiments with one of these machines in 1830: the rotator burst at 156 by the index, therefore the tube ought to be plugged with cane dipped in wax. Although not a favourite in surveying, I should be sorry to detract from its merits; but in surveying operations time is too valuable to sacrifice, when we know that above a certain depth we must stop the line or sacrifice the instrument, as we know the rotator must burst below 160, or cease.

I have never found the instrument I had do its duty, when I made use of it to test some observations for magnetic intensity.

To measure base by sound to the greatest advantage it is preferable to send the boat or vessel with the gun in a direction at right angles to the wind, and the distance not above five miles. Boats should take up positions forming equilateral triangles, at right angles to this base, to windward and leeward, forming a diamond-shaped figure. By this means six measurements are obtained by every pair of guns fired by the vessels alternately; and as in such measurements it is customary to fire three guns from each vessel, we have the mean of eighteen measurements. The effect of the wind is thus in some measure neutralized, but unless conducted by equally expert officers at every station this is not worth consideration. It will be hereafter shown how much can be effected by active and zealous co-operation in conducting such operations in connexion with the other surveying duties.

LOCAL ATTRACTION.—BARLOW'S PLATE.

It has long been asserted, that the proportion of iron in a ship, and even the ship herself, or a log which has long lain in water in the magnetic meridian, particularly if in contact with earths or clays containing iron, affect the magnetic needle. But it remained for Mr. Barlow to convince us, not only of the facts, but to provide a remedy; one which, if closely attended to, renders navigation as much safer than heretofore, as the present perfection of chronometers takes the lead of lunars with crude instruments and imperfect tables. The local attraction in high latitudes may vary 45° to 50°, or more, on opposite tacks, with the wind at north or south. We are not to be surprised, then, when we find former writers stating, "that the compass bearings were found to vary frequently when taking transit bearings of points of land from opposite directions." The wonder is, that they did not vary more, for in one case recorded, the ship was standing S.W. at one bearing, and north the other. Every ship in the service can be, or is, supplied with these plates, but few have yet taken the trouble to have them properly fixed. In vessels intended for surveying, a pillar is secured to the beams, which supports the plate and

azimuth compass, and may be rendered an ornament to the quarter-deck. The most convenient spot, both for use and to be effectual, is just before the mizen-mast. The position of the plate, as regards its distance below the level of the point of suspension of the compass card, as well as its horizontal distance from the vertical line of the point of suspension, is determined by simultaneous observations made on shore with a theodolite, and on board with the azimuth compass, the ship observer having a white staff suspended, and steadily secured, over the centre of the compass—the person on shore a white boarding-pike immediately in line with the ship. The ship is swung, by warps, entirely round the compass. The table of differences supplied with the plate, gives the position for it.* To prove this position, another series of observations should be made with the Plate at its *assumed* mark, particularly when the ship's head is north, south, east, and west. "Gilbert's Azimuth Surveying" is the best compass, as the reading off is very perfectly managed by the prism, enabling the observer to see the object and divisions in contact.

I have before remarked, that excepting in long "running surveys," in deep water, and when the ship's track depends on the compass, it is only made use of by the surveyor as a secondary instrument, and to determine the variation.

It has been remarked by several authors, that the variation cannot be truly observed within half a degree. This may be true, but chance does frequently afford, for days together, observations which (with Barlow's Plate) induce the close observer to come to a different conclusion.

I perfectly remember such a discussion occurring in his Majesty's ship Southampton, on her voyage to India, in 1829. To test this, observations were taken at the following hours, with the results attached.

	h. m.			h. m.	
July 18th, 1829, at A.M.	7 15	0° 23′ 0″ W.	P.M.	3 36	0° 43′ 37″
	8 51	0 29 20		4 36	0 43 58
	9 32	0 36 00		5 36	0 40 26

These observations were made at nearly equal distances from noon, by taking the mean of ten sights at each, by watch, the azimuths being determined by the apparent time.

* Captain Foster found that the rotatory motion of the Plate destroyed the observations, therefore this spindle ought to be square or triangular. His method of obviating this was to unship it, and strike the deck with the circumference held vertically.

This shows how near such observations may be brought by very close attention.

The *method* of observing, and *practice*, will only approximate the truth. Thus the card at sea is constantly in motion, and ship as unsteady. The sun is seen on the dark reflector, and is to be bisected by the silk, with the eye at the same time watching the *extremes* of oscillation. Here lies the secret of observing? The *decision* on the mean of such motion; and should always be repeated ten times. The mean should be accurate; but it may be thought tedious to repeat so many. Let it be done with the watch immediately after the sights for time, which is the most convenient method, taking time only at the first and last observation where the interval is short.

On shore, when the magnetic needle is shifted from one position to another, its change is frequently very perceptible, and not unfrequently the increased dip so strongly affects it as to impede its motion. On volcanic, or granite positions, this is frequently the case, and in sands in which black specks predominate (which generally proves to magnetic iron sand or iserine) it may be suspected.

The first object of the surveyor should be to determine the means at command for carrying his purpose into execution. Whatever his own abilities may be, he has yet to determine those under his directions; he has to teach them his methods, and so to discriminate in issuing his orders, that after the toil of the day is past he may not find, too late, that his confidence was misplaced. These are some of the trials he must *patiently endure*, for the *mind* will not be *driven*; and possibly, at the end of a month, after many bitter pills swallowed, he begins to get the machinery in action. Ability is not coupled with rank; and it may be one unpleasant part of his duty to place the juniors in positions of trust, and thereby cause heart-burnings, which are not readily overcome.

Although his own boat be duly provided, nothing should be left to chance. The executive officers on board should take care that the scale of appointments in each boat is complete before their officers take charge; and we will therefore take the present opportunity of remarking on the equipment of the boats, beacons, &c.

The head sheets of every boat used in surveying should be expressly fitted for the purpose. Too frequently they take the sheer of the boat, which, when the boat rises to meet a sea, throws the leadsman off his legs. They should be parallel to the keel, or, if any thing, depressed at the stem. They should have additional strength,

as the anchors, ballast, stones, &c. are used from that position. Every boat should have an awning stancheon shipped in the step of the foremast, with a guy to the stem-bolt, to steady the leadsman, and enable him to exert his whole strength in heaving the lead. This is material, as it not only saves many a man from going overboard, when his fingers rarely hold by the slippery gunwale, but enables the leadsman to heave sufficiently a-head to prevent the necessity of checking the boat's way to gain bottom. The bows should be strengthened by rubbing bands, which prevents the chafe of the line. Each boat should be provided with two lines of twenty-five fathoms, and two leads.* Each boat should carry an extra man for sounding, so that all the oars may be used;—a spare oar, provision, and water; arms fitted in chests; two anchors and cables; set of boat flags; bag of lime (half gallon.)

Two officers are generally appointed in each boat; one to observe, the other to note. The junior should take especial care that the binnacle, spirits, signal-book, and materials for lighting binnacle, go into the boat *with him;* the superior taking care of his sextant, telescope, and angle-book, in which he should have a pocket for his orders (which should be invariably in writing, as will be noticed hereafter.)

To enable the principal to make use of the observations of those under him, it is absolutely necessary that a perfect understanding should exist on this subject, and that a distinct *formula* should be adhered to, not only in noting the soundings and reducing them to low water, but also in the angles taken, and *solely* to the objects used in the survey, which are communicated by the principal.

To sound judiciously, and accurately, calls for more ability than is generally supposed; the perfect delineation of the bottom is of infinitely greater importance than the trifling about the indentations of a coast which probably cannot be approached within a mile, and the very boundary of which the lead and sextant must define. The orders of the principal may embrace direct lines of soundings, which

* I have found it a material advantage to cut off the old hole of the lead, and bore a fresh one two inches below. Groove the space out with a gouge, and put good *tarred* and *served* strops in, beating the raised edges of the lead *over them.* It possesses these advantages—it is less liable to be cut by the rocks, the man has a firmer hold, and a lead is seldom lost by it. Hide does not answer; it gets ragged, catches the rocks, and not unfrequently, as the lead is held by the strop, a clumsy leadsman will let it slip aft and hurt the bowman.

are required on the chart; but when the limits of danger are to be defined, the abilities of the party must be called in aid.

I shall now proceed with the various formulæ, which were adopted for the survey of the west coast of Africa, and must beg to observe, that where a system has been pursued, differing from my seniors, such did not arise from a difference of opinion, or any fancied superiority in my plans. Had I been taught *any method*, it is probable I should have adhered to it; but having my own ideas solely to guide me, without the aid of books, foreseeing the difficulties which would eventually arise from want of system, in the registry of documents of such importance, I was led to adopt what I have not since had reason to depart from.

In taking angles with a sextant, it must be obvious that, unless back-handed, the object which is reflected is that on the right (or *primary;)* at all events, whether it be back or forward, the *objects* cannot change positions. Under these considerations the *primary* object has always occupied the leading position, as will be thus explained.

Let a series of objects on the horizon be supposed to run in the following order, those having the asterisk being clear, well defined, and calculated to be used as *primary*, and *d* an object to which the sun's image can be reflected.

BY ONE OBSERVER.

	h. m. s.		Times.	⊙	
Comp.	8 20 0 = $\frac{2}{591}$		8 25 10	.... 24° 22′ 30″	
	8 22 42	.. 8674	25 20	———	⊙ *d* — 82° 10′ 15″
Fast	.. 2 42	.. 8674	26 20	.... 24 34 10	

Sextant D 14. Ind. error. — 1′ 20″.

*a**	to *b*	. . . .	34° 10′	
	.. *c*	. . . .	96 50	
	.. *d**	. . . .	126 10	.. 126 10
*d**	.. *e*	. . . . . .	10 1	
	.. *f*	. . . .	14 20	
	.. *g*	. . . .	81 10	
	.. *h*	. . . .	104 20	
	.. *i*	. . . .	122 13	
	.. *k**	. . . .	134 14	.. 134 14
*k**	.. *l*	. . . .	82 20	
	.. *a**	. . . .	99 36	.. 99 36
				360 00

Now it will be evident, that as the primary object cannot be reflected truly beyond 140°, the first clearly defined object supplies its place, and continues the round, those taken to primary being repeated beyond their places, for proof of the correctness of the round. The line on the sun's symbol shows whether the contact was to an object right or left of it—above or below, upper, or lower limb. Surveyors must coin names as rapidly as they proceed; numbers or letters are objectionable on many grounds, and the practice of naming sharpens the wits. The first object is the determination of the astronomical bearing; and by one observer this is attained by first taking an altitude, then the sun to object, and, lastly, another altitude; the time by watch serving to determine (by proportion) the altitude at the moment the distance was taken.

A few moments' consideration will render this example very simple. Thus, let us call *d* Rabbit Peak; then, by subtraction, we find the interval between the altitudes, and the difference of altitude, and by proportion find what it should be at the time corresponding to the middle observation, or sun and Rabbit Peak *right*, the line being on the right side of the symbol, which evinces the contact was made with it. The round of angles is then taken, always naming the *reflected* object as his leading mark, which in the notation speaks for itself; as,

Rabbit Peak and West Bluff . .	34 10
Miller's Thumb . .	96 50, &c.

No one under this *regulation* can *doubt* which is the right-hand object, because he is told *it is to lead.*

Captain Owen's method, which he was kind enough to explain, is also worthy of consideration, and may be preferred. Each is fond of his own adoption.

In noting the above, his method would be decidedly the same in sun and Rabbit Peak, as the Peak is to the right of the sun; but he would say,

West Bluff . . .	34 10	Rabbit Peak.
Miller's Thumb . . .	96 50	Ditto.

because placing them thus shows their position. It is well to sit calmly and reason on this. But place the mass of papers a principal has to investigate, possibly between ten and two at night, and the rapidity of the former method will soon be apparent. One side of the paper is devoted to objects; and in seeking for those most convenient to select for laying down soundings, the eye is naturally led

to the objects, by seeing at once the change to the *next reflected object*, without having occasion to *think*, for the formula has met *my wish*, and the subject is prepared for me. By keeping all the *main* objects on the left, and distinct from the others, the main angles for proving the circle are readily taken at sight.

I prefer carrying the main object to its limits on the arc, (which I frequently do to 146°,) but make the object for superseding it be that nearest to 120°, if it can be conveniently done, *repeating* the small angles before taken. Three angles of 120° must of necessity be nearest to truth, as not only less index error is involved, but the repetition of indistinct objects.

The formula for the ship " Deck-book," when under weigh, will itself explain the data which are there recorded. If she become a *position* on mooring, the principal not only takes *his* round of angles, but they are repeated and registered by every other observer. We will now observe on the arrangements observed by the ship after she has become a *station*, for the intention is first to point out clearly how surveys are to be carried on where little chance of landing offers, or where operations are carried on out of sight of land, in soundings, or outlining dangerous banks. This will afford a clearer insight into the system of marine surveying afloat, and render the subsequent operations on shore still more obvious. In surveys afloat the marks which constitute the triangles are, ship, tender, boats, beacons, assisted by land objects, if attainable. The beacons are constructed readily on board ; for description and plate of which, as well as make-shift moorings adapted for them, *vide* end of work. The ship on mooring shows she is *in position* by displaying her ensign ; she then becomes a principal object, and from her and the tenders every principal occurrence is duly registered. This will be apparent on the formula. The ship having been possibly twenty-four hours in position, has ascertained the velocity, rise, and fall of tide, by noting hourly the depth determined by a graduated pole of fifty feet, ballasted at the thickest end, and kept suspended from the gangway aft ; the mere act of letting go the rope attached to the ballast bringing it instantly perpendicular abreast the gangway: should the depth exceed seven fathoms, the lead-line is used. This is sufficiently true for such surveys, and enables those employed in the boats to reduce their soundings to low-water. A register is thus obtained of the rise and fall, direction and force. If this latter is doubted, and the ship be supposed to be influenced by a current, under-tow, &c., the following should be prac-

tised. Sling two barécas,* and connect them by a line of five fathoms; fill one with water, and add about ten pounds of sand, or a hand-lead; attach the deep sea-line to the centre of the span. It is *convenient* to keep them constantly in the water, veered to twenty fathoms, as they then bear their proper strain, and being clear of the ship, are ready for immediate use. To try the tide or current, ascertain the interval it takes to run out a hundred fathoms, (*i.e.* one hundred and twenty off the reel, allowing twenty for stray line.) This will give a rate free from the influence of *wind* or *surface* current. [I am thus particular on this subject, having in a late survey seen the ship wind-rode, the boats surface-current, and the current-log showing a strong current at variance with both.] A code of signals is established for the boats, and a constant look-out is kept on the working boats. Should any boat get into three fathoms, she anchors and shows her signal for "*danger.*" This is answered by the ship and tenders: angles are immediately taken to all objects, and a series of data thus obtained, which are valuable. The method of registering these motions will be seen in formula at anchor, and the additional data from the tenders are sent by the nearest boat on her return at night. Thus we shall have one volume exclusively devoted to ships' motions; one, boats' motions *observed from ship;* one, register of all angles taken on board tender; one for each barge, (their observations *recorded nightly* when the reports are brought on board;) and *each* officer in command of a boat copies cleanly into a volume entirely devoted to *himself*, his operations of the day. Thus at any lapse of time these materials are clear and comprehensible, and it is only by attention to one complete system this can be done, and no little pride is felt that, the day's work completed, the record stands, and no further explanation called for. The formula is here introduced.

* The baréca is commonly pronounced "breaker" in the service, and spelt barricoe. I have taken the baréca from an old Spanish work, from which I suspect our term had its origin.

FIRST CUTTER.

☾ 5 V/32. Ship at station No. 15 high-water at 4 A.M., fall by tide pole 9 feet 10 inches.

Left ship 5 A.M. for 1st barge, water alongside. 4½ boat's line 4½	—add ½ fm.	Blank for remarks of principal.
4½ mud*. . . . 5 . . . 5¼ . . . 6, 6½ . . 7 sand . . .		
7½ . 5 rocks . . angles 4¾ rocks.. { 2 B . and △ = tender.	82.10	
△ and ship	94.11	
ship (blue beacon)	54.20	
On . 4½ . 3 anchored, showed signal, swung into 2½ sand.... angles. 2½........		
Ship, △, 1 B—answered. (Sun prevents 2 B. seeing me) same objects	81.40 95.10 55.20	
=(weighed) on to 1 B — 3, . 4 . . 5 sand & rock, 7 mud . 9 .		
9½ 1 B. and △ in line, angle to ship	72.10	
9½ . . 10 — at . 1 B answered signal to shift 1 B —		*Principal in pencil.*
On board 1 B . under weigh. [Here note as above the soundings and angles —]		
2 . 30 . anchored 1 B. 3 moored— angles 7½ fathoms, mud .. ... { Ship and △ = tender	*60.20.10	
—— 2 Barge	104.15.20	104.15
—— B beacon ..	128.70.10	
2B —— W beacon ..	80.10	
—— R beacon ..	124.40	124.40
Y B beacon .	140.10	
Red. and ship......	131. 2	131.2
Left, B . on to 2 B. &c. &c.		
		359.57
		—3 ? ind. error

The blank space is left for the principal to make notes or select the angles for proof, &c. as in italics. The nature of the bottom is denoted by symbols, (as in plate, surveying afloat.)

Sufficient has been advanced to enable the beginner to comprehend clearly, that without *method* and *forethought,* surveying is a perplexing operation. It is not to be imagined that without some little practice he can instantly put his work on paper; and to do it *cleanly,* in no small degree marks the ability of the operator. We will therefore observe, that he should take into consideration the space he intends to occupy on paper, and that as his *rough work* is what will be looked to, he should endeavour to commence his operations as if it was his clean copy, keeping the meridian parallel to the side of his paper.

It is to be imagined, as a matter of course, that he has some idea of drawing, and that he constantly takes views of every land he meets, particularly in its *blue distinct outline,* following it up to the head-

* Dots are repetition of figures preceding.

lands, bays, and rocks within the horizon, and that he takes an interest in all astronomical observations. To such a character, then, with his sextant and chronometer as his companions, it is proposed to lead him gradually from Spithead until he meets other lands clearly laid down; there to put in practice the leading formulæ, and if he has not the satisfaction of landing to determine, of approximating the error of his watch. Thence he will be introduced suddenly upon dangers, *out of sight of land*, where the first principles will be put in practice. Thence to the sight of land, but which he can only approach within half a mile, and eventually to some snug spot which will admit of shelter to his vessel, and of which it will be advisable to make an accurate survey with sextant only.

At Spithead, he has the opportunity of determining his rate and error, by the ball shown at the dock-yard at 1 h. 0′ 0″ mean time at Greenwich. This is very *convenient*, and an excellent *test*,—but we want more than this—*confidence* in his *own observations*, and the *habit* of taking advantage of every chance which offers. This is indispensable, and he cannot better occupy himself than by rating his own chronometer, determining daily from such position the true bearing of some distinct object, and its angle to his ship's foremast, as well as the latitude. This will afford him the means of taking advantage of every spare moment in determining the variation on board. He may take angles from these two positions to principal objects, and if a gun be fired obtain a base. The investigation of these triangles referred to the chart will afford him an estimate of his own abilities, which cannot fail to be of the utmost importance to *himself; even if humiliating*, PERSEVERE. Truth, when it does come, will be doubly sweet. In determining the rate of a chronometer, the method by equal altitudes should invariably be adopted, as an erroneous latitude will not (as in single) materially affect the result, and the latitude may be inferred from them. In taking such observations, each observer has his favourite method; some prefer setting the sextant to an altitude, and letting the upper limbs come in contact, the centres, and lower, and putting the sextant bye with the index fixed until the afternoon, when the corresponding observations are taken. [It not unfrequently occurs to the surveyor, that he is compelled to watch a half-tide rock or reef to obtain his observations, which barely admits of his obtaining equal altitudes at some distance from noon, and that even if it happened to afford safe landing at that period, the sun being nearly vertical, could not be observed in the artificial horizon. The

method by altitudes off the meridian will then be of importance.] There are various objections to this method, and that which must be apparent to every observer is the *doubt*, in many climates, that the sun may be *visible*—that the observer, unless that be his sole occupation, can get back at the precise instant—and that in most instances the sextant is to go on board, and will not go into its case* unless the vernier be at zero.

To obviate these disadvantages, and afford more materials for other objects, it is preferable to commence at 9 h. at an even degree, and take the sun at every 10′ for 2°, (making thirteen sights.) When half an hour has elapsed, a similar set, &c. making at *least* three sets of thirteen. If I am *anxious* about a position, I sacrifice six hours, from nine until three, as will hereafter appear. Great scope is thus afforded, and the loss of a set is not so material; for we are to bear in mind that the wave is uncertain; we have to determine the latitude, (which should be done also by circum-meridian altitudes,) be on board for comparison at one, and back again at 1 h. 30′. In making such observations, a good pocket watch may serve the purpose, and prevent moving the chronometer, but a comparison should be made before going on shore,—on shore by flag, and on return. A point is deserving of notice here. Chronometers should never change their *relative position* on board. They are affected by local attraction, and even turning the face one-fourth will affect the rate. In whatever direction, if 12 h. be originally placed, that should be adhered to.

We will suppose, then, that the chronometer has been rated, and that a little practice in other points has given the party confidence, and a determination to follow it up, as far as occasion offers. We will imagine that observations A.M. and P.M. for longitude and variation are eagerly pursued, as well as latitude at noon; that the ship is truly placed by incessant practice,—in fact, that sun, moon, and stars have no rest.

In a short period land is discovered, about three points on the starboard bow, and at 9 h. 30′ sufficiently distinct to make use of from the deck. How stands the reckoning? and what is to be done to ascertain, as well as to put some of the principles of surveying in action? If there be a patent log on board it may now be called into play—if not, the old method must be substituted. Let the log be hove, and the ship carefully *steered*. If assistants are at hand, let

* Square sextant cases are preferable on this account.

one take time, another the sun's altitude, and the third measure the angular distance between the sun and some defined object at the horizon, taking the precaution, if the sun's bearing be not more than 40° from the nearest object, to carry it to an object 70°. or 80°. Then take angular measurements between the extremes of all objects in sight, (referring the principal in connexion with that to which the sun was taken,) and the best defined object should be accurately set by compass. Sets of sights for chronometer should be taken before and after, and views of the land, with the measurements both horizontal and vertical, should not be neglected.—*Vide* Plate of Island, No. I.

When the bearing of the principal object taken by the compass has changed about 45°, get another set of similar observations. At noon take great pains in determining the latitude, and the time by chronometer, if computed, will afford the instant the sun is on the meridian. The angular distance between it and the object should be taken, and the principal angles repeated. These observations to be repeated as often as the changes of bearing will afford a difference of 40° or 45°: and they will be more complete if such occur when transit bearings come on, (that is, when the north extremity of the island comes in contact with the south of another, or two points in line.) These observations, astronomically determined, are *always important*, even if they be not coupled with any other data, and will always prove acceptable to the Hydrographical-office, but more particularly if soundings at the same instant be obtained, and an angle of 50° to 60°, or more, be taken to some object on the chart. By similar means most important errors have been detected. We will now proceed to work out and show the simplicity with which such observations will either place the ship in her true positions on the chart, or afford the means of detecting and correcting such errors as may be found. We will, then, take the following as an illustration, in connexion with Plate I.

On the 1st May, 1834, at eight observed the land about one point on the starboard bow; about $9^h\ 30'$ (smooth water and very clear day) determined on proving the reckoning. Put the patent log over, and steered S. 41° 30′ W., so as to bring the objects well on the starboard bow, and prevent the action of leeway :—

The following observations were then taken :—

Time. ☉ No error. ☉ So tang. outer island.

♃1 V/34 9 35 52 52° 25′ 31″ 111° 34′ 00″ Dip 18 feet.

Lat. by acct. 33° 8′ N., long. chron. 16° 10′ W.

Dec. . . 15° 0′ 48
Corr. . . 1 0
Cor. dec. 14 59 48
Pol. dist. 75 0 12

h. m. s, ☉ ☉
9 35 52 52° 25′ 30″ 111° 34′ 0″
Sem. di. 15 53 15 53

App. 52 41 23 App. dist. 111 49 53
Dip 4 11

A. alt. 52 37 12
Ref. 39

True alt. 52 36 33

Lat. . 33 8 0 .... Sec. 0·077067 A. dis. 111 49 53
T. alt. 52 36 33 .... Sec. 0·216633 *a. a.* 52 37 12 .. Sec. 0·216741

Diff. 19 28 33 Sum 164 27 5
Pol.dist. 75 0 12 Diff. 59 12 41

Sum 94 28 45 ½ sum 82 13 32·5 Sine 9·995990
Diff. 55 31 39 ½ diff. 29 36 20·5 Sine 9·693752

½ sum 47 14 22·5 .... Sine 9·865814 19·906483
½ diff. 27 45 49·5 .... Sine 9·668225

63 53 13 Sine 9·953241

19·827739

127 46 25 = hor. ang.

55° 5′ 43″ Sine 9.913869

N. 110 11 26 E. Cosine 111 49 53 — 19·570399 = + radius.
Cosine 52 37 12 — 9·783259

S. 69 48 34 E.
Hor. ang. 127 46 26 127 46 25 cosine = 9·787240 (proof of above.)

S. 57 57 52 W. true bearing of object.

° ′ ″

Thus then true bearing of S.E. tangent of Bluff Island = S. 57 57 52 W
(The same line cuts the visible extremity of the southern low island.)

Angles taken at time: centre of North Rock, (Flemish Cap) and transit of N. extremity of island, and S. of N.W. rock (seen from mast-head) . . . } 2 50*

(N. Rock,) Flemish Cap, and North Peak . . . 7 19 elev. 45′ 10″.

Flemish Cap and Middle Peak		10° 37′
S.E. Island Bluff	. . .	17 42*
(N. Peak of Low Island in line.)		
S. extreme (to which ⊙ was taken)	.	21 23

Sights were taken also for Longitude by Chron.

	° ′ ″
Results from above: true bearings, S.E. tangent, Bluff Island, and edge of cliff of Low Island	S. 57 57 52 W.
N. tangent of Great Island, and S. of N.W. rock . . .	*S. 76 30 53 W.
S.E. tangent of island, and small N. Peak of Low Island . .	*S. 61 38 52 W.

For Middle Peak, elev.	Mean on arc. . . .	49° 35′
	Arc excess .	51 45
	Mean . .	50 40

Magnetic bearing of Middle Peak . . N. 88 0 W.

At 10° 30′ wind falling, examined patent log, and found the distance run to be six and a half miles, which agrees exactly with the log board. Obtained sights for chronometer, and the following observations :—

h. m. s.		⊙ L. L.	⊙ S.E tang. of Bluff Island, and S. of Great Island in one.		
10 30 0		62° 26′ 0″	105° 49′ 0″	Dec.	15° 0′ 48″
	Sem. dia.	25 53	15 53		18·8
		62 41 53	106 4 53		15 0 29·1
	Dip.	4 11		Pol. dist.	74 59 31
	A. a.	62 37 42			
	Ref.	26			
	T. alt.	62 37 16			

Lat. .	33° 3′ 10″	Sec.	0·076669	App. dist.	106° 4′ 53″		
T. a. .	62 37 16	Sec.	0·337362	A. a.	62 37 42	Sec.	0·337468
Diff. .	29 34 6			Sum.	168 42 35		
Pol. dist.	74 59 31			Diff.	43 27 11		
Sum. .	104 33 37			½ sum.	85 21 17·5	Sine	9·997888
Diff.	45 25 25			½ diff.	21 43 35·5	Sine	9·568409
½ sum	52 16 48·5	Sine	9·898183				19·903765
½ diff.	22 42 42·5	Sine	9·586695		63 31 27	Sine.	9.951882
			19·898909		127 2 54	hor. ∠.	
	62 53 23	Sine	9·949454				
	125 46 46						

S. 54 13 14 E. ⊙'s true bearing.
Hor. ∠ 127 2 54

S. 72 49 40 W. True bearing of S.E. ext. of Bluff Island, and S. of Great Island.

* Those starred are transit bearings.

∠s. taken, N. tangent of Flemish Cap. and N. ditto. of		No. 2, rock .	$5^{0}\ 22'$
		3, . .	10 32
		N. tangent island, and S. No. 3. .	12 9*
	(∠ elev. $1^{0}\ 15'\ 0'$)	N. Peak . .	10 30
Arc, on . . 1 24 5 off . . 1 26 5	} $1^{0}\ 25'\ 5''$	Middle . .	24 40
	S.W. Peak in line	S.E. Bluff . .	36 4*
(Transit objects ⊙) —		S.E. extremity of Bluff Island, and S. of Great Island	40 34*
		N. extreme Flat Island .	41 21
Middle Peak N. $68^{0}\ 20'$ Mag.		S. Peak .	46 25
		S. Xme. .	48 20

The wind failing, no dependence can be placed on the run from this period. But as two sets of angles have been obtained, it will not be difficult to bring the ship again into connexion with the former work, provided the base determined on shore can be brought into play.

The longitude by chronometer has been determined by sets of observations at the extremities of the base to be as under.

h. m.			
At 9 36 = $16^{0}\ 10'\ 0''$	By chart	$16^{0}\ 0'\ 50''$	Error $0^{0}\ 9'\ 10''$
At 10 30 = 16 16 10		16 6 5	„ 10 5
		Mean A.M.	9 37·5

At 4h. 24m. 10s. P.M. sights were again obtained for the chronometer, and the following angles and observations made.

	$\underline{\odot}$	$\vert\odot$ N. tangent of Great Island.	
$4^{0}\ 21'\ 10''$	$27^{0}\ 51'\ 12''$	$53^{0}\ 47'\ 20''$	Dec. $15^{0}\ 0'\ 48''$
	15 53	15 53	4·85
	28 7 5	53 57 13	15 4 56·5
	4 11		74 55 3·5
App. alt.	28 2 54		
	1 41		
T. alt. .	28 1 13		

Lat. .	32 58 0	Sec.	0·076245	$53^{0}\ 57'\ 13''$		
T. alt.	28 1 0	Sec.	0·054132	28 2 54	Sec.	0·054260
Diff.	4 57 0			82 0 7		
Pol.dist.	74 55 4			25 54 19		
Sum.	79 52 4			41 0 3·5	Sine	9·816951
Diff.	69 58 4			72 56 9·5	Sine	9·350531
						19·221742

* Lat det[d] from compass bearings of land.

				19·221742
½ sum. 39 56 2	Sine 9·807470			
½ diff. 34 59 2	Sine 9·758418		24 5 30 =	9·61871
	19·696265	hor. ∠. 48 11 0		
44° 49′ 20″	Sine 9·848132			

☉'s true bg. S. 89 38 40 W.
Hor. ∠ . 48 11 0

137 49 40

N. 42 10 20 W. = true bearing of N. extreme of Island.

The following angles were then taken.

	N. tangent, Flemish Cap, and N. extreme of island	10° 10′
	No. 2 Rock	2 15
	No. 3	5 58
∠ 1° 14′ 0″	N. Peak	18 49
Arc. on . 1° 24′ 5″ / off . 1 26 5 } ∠ 1° 25′ 5″	Middle	24 37
	S. extreme of Island	48 40
	N. extreme of S. Island	49 50
	S. ditto	58 46

Middle Peak N. 33° 30′ W. Mag.

Having now completed the bearings, we will refer to the chart, bearing in mind that every object to which an angle has been taken has an astronomical bearing, which is simply obtained by applying the angle between it and the object to which the sun was taken. Thus we wish the true bearing of the Middle Peak, the angle, Flemish Cap, and N. extremity = 10° 10′, ditto to the middle peak 24° 37′, the diff. = 14° 27′ left of the N. extreme.

The true bearing of the N. extreme is	N. 42° 10′ 20′ W.
+ =	14 27 00 left.
True bearing of Middle Peak	N. 56 37 20 W.

Draw a meridian through some part of the island; select those bearings which subtend the greatest angles, and particularly those which have two objects in line. In the first set of angles, first draw the true bearing from the Flemish Cap, North Rock; then through the S.E. extreme of Bluff Island, remembering where it cuts the Southern Island. There is also a N. line which cut the N. extremity of Great Island, and the S. of N.W. rock: these should

all meet in one point, if the chart be true; if they do not, find any three which agree, and fix on that point for your station, and lay off the angles from it, taking care to include *extreme objects*, unless they alone appear faulty.

From that point lay off S. 41° 30′ W. six miles and a half, (taken from the latitude gradation in the same parallel.) If no current exists, or the ship has been truly *steered*, the next set of angles should cut the objects from thence; particularly, as two transit bearings should secure this position, viz. the N. extreme of the island, and S. of No. 3—the S.E. of Bluff Island and S. of Great Island. If the true bearings *from* the position do not agree, try them *from* the objects themselves, and also if the other angles will coincide; if not, the chart is erroneous, and the documents you have important. Lay them off on a clean sheet of paper, adopting the course S. 41° 30′ W., six miles and a half as a base, and compute the distances between the objects, if so inclined; but the whole may be simply projected on paper. The afternoon position, as will hereafter be shown, is not LOST. Many are too apt to throw away documents of this nature, because "*patience* and *perseverance*" are not called in aid. The base and previous angles will determine Flemish Cap and Middle Peak. The true bearings *from* these will cut the afternoon position, (if not computed,) and by this means the completion of the *extremes* of the island on three sides will have been pretty fairly attained. Thus may every ship of war test our charts. The rough work and data are always acceptable at head-quarters, and are infinitely more valuable than sheets of *remarks* without *documents.*

It will here be apparent how cautiously surveyors should be in determining their lines of bearing between all objects on the *extremities* of the land. This perhaps is marred by some want of caution in squaring off for reduction, on which it is intended hereafter to make one or two remarks, under that particular and most important duty.

We will now proceed to investigate the work, and how very simply the materials can be put into shape, and tested.

The 1st triangle gives us as base S. 41° 30′ W. six miles and a half.

Then, calling the 1st station *a*; 2nd *y*; Flemish Cap, *x*; High Peak, △.

$$\left.\begin{array}{l}\text{True bg. Flemish Cap} = \text{S. } 79^\circ\ 20'\ 52''\ \text{W. from 1st station}\\ \qquad\qquad\qquad\qquad\ \ \text{N. } 66\ \ 36\ \ 20\ \ \text{W. from 2nd station}\end{array}\right\} = 108^\circ\ 6'\ 20'' = \text{ang. at } y.$$

The diff. between the course, (see plate I.) and Flemish $= 37^\circ\ 50'\ 52'' =$ ang. at *a*.

$$\begin{array}{l}\\ a = 37^\circ\ 50'\ 52''\\ y = 108\ \ \ 6\ \ 20\\ x = 34\ \ \ 2\ \ 48\end{array}\left\{\begin{array}{lll}\text{Base} & 6'\cdot5 & = 0\cdot812913\\ & 6075\cdot6 & + 3\cdot783589 \text{ or No. of feet in geogra. mile.}\\ & & \overline{\qquad\qquad}\\ \text{Feet,} & 34{,}489 & = 4\cdot596502 = 6',5 \text{ miles.}\end{array}\right.$$

	Then, as x 44° 2′ 48″ sine co. ar. (*or Cosec.*) .	0·251914
	Is to the base	4·596502
(1.)	So is y=108° 6′ 20″, sine . . .	9·977946
	To a x=ship to Flemish Cap=67044=	4·826362

	Again, as 34° 2′ 48″, &c. . . .	0·251914
	: Base	4·596502
(2.)	: : 37° 50′ 52″=(a)=sine . . .	9·787861
	To 2nd station 43279=	4·636277

	Second triangle, 2nd.—ang. at y = . .	24° 40′ 0″
	Whole angle to last position . . .	108 6 20
		132 46 20
(3.)	∠ a=	27 13 52
		160 0 12
	∠ at Mid. Peak	19 59 48

Then, as 19° 59′ 48″. (cosec.) . .	0·466018
: Base	4·596502
: : 132° 46′ 20″ (sum of angles at y) .	9·865731
a to Peak △ . . . 84722 =	4·928251

4·928251 = a to Peak △.
3·783589 = (6075,6)

1·144662=13′·95 miles.

To determine the angles of the northern obtuse ∠ △.

Side a x = 67044		∠ at a — 10° 37′ 0″
a △ 84772		169 23 0
Sum of sides 151816		½ sum angles 84 41 30
Diff. 17728		

(4.) Sum.	As 151816 co. ar. . . .	4·818711
Diff.	: 17728 = . . .	4·248660
	: : 84° 41′ 30″ tang. . . .	11·031919
	51° 29′ 36″ tang.= . .	0·099290

51 29 36
84 41 30

136 11 6 = ∠ x^2

33 11 54 = ∠ △.

(5.) As 132° 46′ 20″ (sum at y) = sine. co. ar. (*Cosec.*) 0·134269
: 84772 . . . . 4·928251
: : 27° 13′ 52″ . . . . 9·660468

y = △ 2nd position to peak = 52843 = 4·722988

Now, having these sides on a fairer triangle, we will compute the angles again contained in the 2nd acute △.

(6.) 52843.	24° 40′	77° 40
43279.	155 20	24 28 8
96122. Sum.	77 40	102 8 8
9564. Diff.		53 11 52

As 96122 co. ar. . . . 5·017177
: 9564 . . . . 3·980640
: : Tang. 77 40 . . . . 0·660261

24° 28′ 8″ tang. 9·658078

To prove the distance △ x

At 53° 11′ 52 sine co. ar (*Or Cosec.*) . 0·096526
: 43279. base $x\,y$ . . . . 4·636277
: : 24 40 „ sine . . . 9·620488

△ x : 22557,6 . 4·353291

And as 102° 8′ 8″ — cosec. . . . 0·009815
: Base 53843 y^2 △ . . . 4·722988
: : 24 40 sine . . . 9·620488

: △ x 22557·6 = 4·353291

The base then we have determined is Middle Peak and Flemish Cap, equal to N. 35° 31′ 48″ E. 22·557,6 feet. Now, having this as base, and the two true bearings to these objects, it is evident one side and all the angles are given to determine the distance from the Middle Peak or Flemish Caps.

The examples worked are sufficient in this place; we will now proceed to determine the height of the Middle Peak.

The determination of the height is a simple question in plane trigonometry, in which we have the distance, and angle of the most elevated point. Such will afford the "tangental" height, (if I may be permitted the expression,) or that which the horizon would bisect of the perpendicular. To obtain this, we use either of the subjoined formulæ:—

As ar. co. of the cosine of the altitude corrected for dip and refraction.

: Distance of the object in feet.

: : Log sine of the corrected altitude.

: To the elevation, +, the depressed portion.

Or, as rad. : base : : tangent angle of elevation : height as above.

By Raper. To the constant log 3·783589, (the log of 6075,6, the number of feet in a nautical mile,) add the log. of the distance, in miles and *decimals*, and the log. tang. of the alt. (corrected.) The natural number of the sum being added to the number from the following table is the height in feet.

TABLE.

Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.
1	0.9	7½	49.7	11	107	14½	183	18	286	21½	408
2	3.5	8	56.6	11½	117	15	199	18½	302	22	428
3	8.0	8½	63.9	12	127	15½	212	19	319	22½	447
4	14.1	9	71.6	12½	138	16	226	19½	336	23	467
5	22.1	9½	79.7	13	149	16½	241	20	353	23½	488
6	31.8	10	88.4	13½	161	17	255	20½	371	24	509
7	43.3	10½	97.4	14	173	17½	271	21	390		

This table is to be entered with the difference between the distance and the *true* dip of the observer in miles.

We will give the three methods, then, on the same object.

The ∠ of elevation at station I. is 50′ 40.

First, the dip of the observer, by Raper's rule. To half the log of the height of the eye in *feet* add the constant log. 6·49057, the sum is the log tangent of the dip: or, arithmetically, extract the square root of the height and multiply it by 1,063, the product is the dip in minutes and decimals. This is the *true* dip, that in the tables is the *apparent*, which is one-twelfth less from the effect of refraction.

By Galbraith. To the constant log 3·60999 add the height of the eye in feet, half the result equals the dip in seconds; from this subtract one-twelfth for refraction, and the apparent dip is the result.

	Then by Raper—Eye 18 feet ½ log	0.62768	Galbraith	3.60999
	Const. log	6.49057	18 feet	1.25527
	Tang.	7.11825		2)4.86526
True dip 4′ 31″				
1-12th 22.58			270·8=	2·43263
App. dip 4′ 8″.42			Ref. 1-12th =	22·57
				248·23=4′ 8″. 23

Alt. 0 50′ 40″	As Cosi. 45·23. co. ar. = (Sec.)	0·000038
1-12th dist. 1 9	: base. 84772 feet	4·928251
	:: sine 0° 45′ 23″	8·120610
49 31		
Dip 4 8	: 1119·2	3·048899
45 23		
	Or as rad.	0·000000
	: base	4·928251
	:: tang. 0° 45′ 23″	8·120648
	: 1119·2	3·048899

By Raper :	Log. dist. in miles 13·95	1·144662	} =4·928251
	(6075·6)	3·783589	
	: tang. 0. 45. 23	3·120648	
	1119. 2	3·048899	

Thus the principle is clearly to be seen, because the log of the distance in miles, added to that of 6075,6 = the distance in feet, added to the log tang. of the ∠ of elevation = the height.

But Raper's method differs from the above by simplifying the correction for dip, &c. He takes the altitude simply corrected (for the

refraction on the intercepted arc,) and subsequently applies his correction from his table, which will be presently shown.

Thus, dist. in miles 13′,95	1·144662	Dist.	13·95
Const. log (of 6075·6)	3·783589	Dip.	4· 5
Tangt. of ∠ 49·31	8·158508		
			9·45
1221·1 =	3·086759		
Dist. to 9·5 = 79·7			
1300·8			

Thus, then, we are freed from a calculation for the depressed proportion. But this must not be; we must proceed to determine it without the help of such tables.

*The mean diameter of the earth may be assumed at 7912 miles, or 41775360 feet. The rule, therefore, will be: Multiply the log. of the distance in feet by two, and divide the natural number resulting by 41775360, the quotient = the depression sought.

Or simply: to the arithmetical complement of the log. of the earth's diameter (41775360 log. 7·620920) = 2·379080 add twice the log. of the distance in feet, the sum (rejecting tens in index) will equal the depression sought.

Thus, then, we have		4·928251 log of dist. in feet.
× 2	=	9·856502
Const. log.		2·379080
172·02		2·235582
Former height by calculation 1119·20		
Height 1291·22		
Raper 1300·80		
Difference 9·58		

For common purposes, then, this difference is trifling.

Using Raper's method, then, we will compute the elevation from the second station.

* Elements from Galbraith.

Observed altitude $=1° 25' 5''$		Distance $8'{\cdot}7$ or 52843 feet	$=4{\cdot}722988$
Cor. for dist.	43	$\div 12$	1·079181
Cor. alt.	1 24· 22	4403 feet	3·643807
			3·783589
		× by 6=43″,488=,7248	9·860218

Dist. in miles 8·7 . .	=0·939519	Dist.	8·7
(6075·6) const. log . . .	3·783589	Dip.	4·5
: Tang. 1.24.22 . . .	8·389984		4·2
	1297·4=3·113092		
From table 4·2 =	16·1		
	1313·5		

Now as the third position by *projection* appears to be the same distance, and we have also the same altitude, the same result must follow.

Therefore at I. position, height	1300 feet.
II. . . .	1315·5
III. . . .	1315·5
Mean height	1310·3

Now supposing this height to have been noted on the chart, or the elevation given elsewhere, we will try what distance the rule would have given.

In the first instance, then, at Station I., we have observed altitude 50′ 40″.

50′ 40″
1 9 for ref. $\frac{1}{12}$ intercepted arc.
49 31 or 49·5

Then	49·5	Dip to 1300 feet.	
Dip	4·5	1300 ½ log.	1·55697
(*a*) Remainder	45·0	Const. log.	6·49057
	45		
	225	Tang =0° 38′ 21″ =	8·04754
	180	Or $\div$6=0 38. 35	
1st product	2025	Then 0° 38′ 35″ dip to 1300 ft.	
2nd product	1450·5	Dip 4 5 eye.	

	2) 3·541017	log. = 3475·5	Sum.	42 85	log 1·631951
Root 58·95	= 1·770508		Diff.	33 85	1·529559
Remaind. 45			2nd product	1450 5	3·161510
Dist. 13·95					

Second Station. Observed altitude 1° 25′ 5″; distance 8′,7 miles.

1° 25′ 5′	Then 84″,36 alt. in seconds and tenths.		Dip to 1300 feet, as before.	
43 $\frac{1}{12}$ arc.	Dip	4. 5		
1 24 22=84″,36	Rem. *a*. 79 86	1·902329²	1450·5 = 2nd product as before.	
	1st prod. 6377·6	3·804658=1st. 6377·6		
		Sum 7828·1	= 3·893657 ÷ 2	
		Square root 88·48	= 1·946828	
		Remainder (*a*) 79·86		
		Dist. 8·62 miles.		

Rule (Raper.) Take the dip of the eye (the *true dip* as above) from the altitude observed, and multiply the remainder by itself.

Multiply the sum of the dips (of eye and object) by their difference, and add this product to the other. Extract the square root of the sum, and from it take the above-mentioned remainder, the result is the distance in miles from the summit.

If this distance differs from that assumed in the altitude, repeat the operation with the new distance (for intercepted arc.)

By logarithms. Multiply the log. of the remainder (*a*) by two, and find the natural number, which call, first product; add together the logarithms of the sum, and difference of dips, and call the resulting natural number, product two. Add one and two together, and divide the log. of the sum by two, (which is the square root,) from this number subtract the remainder, (*a*) and the result is the distance in miles.

We will now proceed to tabulate the results, and show what a few hours' attention have produced.

The mag. bearing of Middle Peak from I. N. 88° W. True S. 68. 43. 52W.		23°	16′	8″
II. N. 68. 20 W. True S. 88. 43. 40W.		22	56	20
III. N. 33. 30 W. True N. 56. 37. 20W.		23	7	22
Mean variation		23	6	36

The direction of the ship's head should be noted at each bearing, and is important if Barlow's plate is not used.

True Bearings.	Objects and Transits.	Referred to Middle Peak.	Dist.	Diff. Lat.	Diff. Long.	Latitude of Peak.	Longitude of Peak.	Elevation.
I. Station.								
		° ′ ″		′ ″	′ ″	° ′ ″	° ′ ″	
S. 57. 57. 52 W.	S.E. tangent Bluff Island, cuts cliff extremity of Low Island							
S. 76. 30. 52 W.	North tangent Great Island, and South tangent of N.W. Rock.	S. 68. 43. 52 W.	13,95	5. 3,6	15. 31,2	33. 2. 56,4	16. 25 ·31,2	1308
S. 61. 38. 52 W.	S.E. tangent Great Island, and North Peak of Low Island.							
II. Station.								
S. 72. 49. 40 W.	S.E. extremity of Bluff Island, and South of Great Island....................							
S. 77. 19. 40 W.	S.E. Bluff and S.W. Peak in line	S. 88. 43. 20 W.	8,7	0. 11,3	10. 8,4	33. 2. 58,7	16. 26. 18,4	1315,5
N. 75. 45. 20 W.	North tangent Great Island, and South of No. 3 rock.					Mean A.M.	16. 25. 54,8	
III. Station.								
N. 42. 10. 20 W.	North extreme of Great Island	N. 56. 37. 20 W.	8,7	4. 40,2	8. 27,6	33. 2. 40,2	16. 25. 57,6	1315,5
Mean variation 33° 6′ 26″ W.				By authorities		33. 2. 51,7 33. 3. 0	16. 25. 56,2 16. 16. 50	1310,3 1300
				Errors		8,3	9. 6,2	10,3

The chronometer then is 9′ 6″,2 in error, or 36,4 seconds to the westward, or too far a-head, on Greenwich time.

This part of surveying has been dwelt on, because the opportunities for practice are daily occurring; and one principal object in view is to induce those who make such observations to register them in a distinct *form*, so that the results, as well as the whole rough work, may be available.

In the Plate (I.) which is connected with this, the vessel's track is continued into port, that she may be enabled to rate her chronometers, &c.

Now, the soundings, as explained hereafter, could readily have been laid down by taking angles to three defined objects, and the method of performing this operation by surveyors is chiefly by station pointer. It frequently happens, however, that a vessel may be blown off during the night, and may wish to resume her operations in connexion with her former base. This is easily attained, by getting on a transit or well-determined bearing, backed by an angle of at least 50°, to another well-determined object. Instruments are not trusted in such operations, and therefore we must have recourse to trigonometrical calculations, or geometrical projections, which will be here introduced, previous to proceeding to the rough survey on shoals.

The positions for soundings are generally laid down by the station pointer; but it frequently happens that a station (particularly in surveys afloat) involves lines of direction, by which the coastline is determined, and in such cases it is safer to calculate or project the figure, for the explanation of which, the following geometrical problems have been introduced.

Plate II. fig. 1, An angle at the centre of a circle is measured by the whole arc on which it stands, as $a = 60°$.

An angle at the circumference of a circle is measured by half the arc on which it stands; as in same figure, b, is on the circumference of the circle, of which a is the centre; and the angles at the extremities of the base will be equal, equal to half the difference between the angle at the circumference − 180 as $30° - 180 = 150° \div 2 = 75°$.

If the circumference of a circle be described touching the extremities of a straight line, that line becomes the chord of a circle, the centre of which is to be found on the perpendicular raised at the centre of that line.

Thus, the centres of all the circles described in fig. 1, as touching the extremities of the base e, f, are to be found on the dotted line

c, *d*, which line divides *e f* at right angles to its centre, and consequently forms two right-angled triangles.

Upon the above principles, two objects can be seen under the same angle *only*, from some part of the circumference of such a circle at *double* the angle. As the base, *e*, *f*, can only be viewed at an angle of 30°, on some part of the circle of which *a* is the centre, and a measure of 60°, or double that at the circumference.

A familiar illustration will do more in impressing this position, and pasteboard, or horn diagrams, would effect more than pages of explanation.

Thus, cut out in card the triangle *b*, *e*, *f*, (increased to treble dimensions,) leaving a spare piece on *b* for a *centre hole;* describe the circle increasing all the dimensions to treble; place pins firmly through *e* and *f*, and pass the *pencil* through the *centre hole* at *b*. Move the triangle right or left, bearing on the pins, and it will be found that it will describe the same circle, illustrating, that the base cannot be viewed, but under the above conditions, at any part of the circumference.

If the angle under which the objects are seen, or the base subtends, be less than 90°, the place of the observer must be somewhere in the greater segment; if the angle be greater than 90°, in the less.

In order to determine the centre of any such required circle, it is evident, then, that as the angle measured at the centre is double that at the circumference, we immediately obtain the centre on the condition; that on the line bisecting the base will be found such centre; that such line divides the base into two right-angled triangles; and that the angles at the extremities of the base are equal to half of what it wants of 180°. Therefore, if at either extremity such angle be laid off, it must intersect the perpendicular *c*, *d*, at the required centre; because the angle at *a* will then be exactly what *e* or *f* wanted of 90°.

If, therefore, we have two known *adjoining* bases, or only known by *projection*, we obtain the position of an observer by projecting circles, corresponding to double the angles under which the bases were viewed, their intersections being such a point on the circumference of such circles, from which such objects could only be viewed, under the given angles.

It is to be remarked, that where the bases made use of form an angle near to, or little exceeding 90°, the position of the observer may fall on the circumference of a circle common to both bases, as

in fig. 2, or cut so obliquely as to prevent the station from being satisfactorily determined.

We will now proceed to examples founded on the foregoing, and endeavour to meet such cases as generally occur in practice. Selecting the simplest, we shall proceed to show that a station may satisfactorily be fixed by one angle only, if two other known objects can at the same instant be brought truly in line. It is always advisable to secure as many corroborative as can be obtained, as not only more satisfactorily ensuring the position, but testing the accuracy of previous projection, a source of infinite satisfaction to the surveyor.

Example I—(Fig. 3.)

Fig. 3—Anchored in a position, having the peak *a*, and the tangent of the bluff in line, angles were taken, *c* and objects in line 21 45, *c* and $b = 91^\circ\ 15'$.

Now, the line of *direction* being drawn from *a* through the bluff, must be that on which the observer was situate. The angle which *b* and the bluff made must be known, therefore $21^\circ\ 45' - 91^\circ\ 15' = 69^\circ\ 30'$; consequently, by adding it to the known angle at *a*, and subtracting the sum from 180°, the angle at *b* results, which being laid off, will afford one intersection. Again, *a*, *c*, being known, a similar proceeding gives the angle at *c*, and the intersection of the three lines verify the position. Now it will occur to the beginner, Why were not the angles measured as in the diagram? Because it is better to refer all angles to the primary *distinct* object; and *a* being a peak, and not so near the same level as *c* and *b*, the angle is more truly measured, *c* being a *station*, having a *clearly defined mark*. One angle would have been sufficient, as the larger $= 69^\circ\ 30'$. Now the station pointer would have settled this problem instantly, by laying off $21^\circ\ 45'$ on the right radius, and $69^\circ\ 30'$ left, the zero corresponding to the "*line of direction.*"

If computation be necessary, it is clear that the sides *b*, *a*, and *a*, *c*, being known, with the angles at *d*, the result is simply obtained.

We now come to the next example of two angles taken on two adjoining bases, without a line of direction or true bearing.

In order to render this problem clear, we will project the triangle with its known sides and angles, as on the plan, and proceed to show how the position may be determined by protraction and calculation.

Example II

Let A, B, C (fig. 4) be the positions on the plan where the angles and distances are as follows. Angle at A $22^{\circ}\ 20'$, B $= 140\ 40$, C $= 17^{\circ}\ 0'$, A B 4,01, A C $= 8{,}70$, B C 5,22.

Pulling in a boat we suddenly came into one fathom, and immediately anchored, found four feet astern, veered boat over the spot, steadied her by oars to the bottom, and showed danger signal (for stations to take angles to.) Observed C B $= 49^{\circ}\ 0'$, and B A $= 42^{\circ}\ 30'$, required the position of the boat? Now the angle at the centre of the circle is equal to double that at the circumference; or, the angle of the right-angled triangle will be the same as that at the circumference. Thus, C B $= 49^{\circ}\ 0' \times 2 = 98^{\circ}$, and $98 - 180^{\circ} = 82^{\circ} \div 2 = 41^{\circ}$; or the complement of 49° taken on the right angle triangle $= 41^{\circ}$, therefore, bisecting the bases centrally, and laying off the complements of the observed angles, we obtain the centres of the circles D D′, the circumferences of which touch the extremities of their corresponding bases. The point of intersection, then, $= x$, is the position required.

Second Method.

Draw the base between the extreme objects. At A lay off the observed angle C B $= 49^{\circ}$; as C′, A, C. At C lay off the other angle $= 42^{\circ}\ 30'$ C′, C, A. From the lines of intersection at C′, produce the line C′ A indefinitely. Describe a circle which shall include the points A, C′, C, and where it intersects the indefinite line C′ A x will be the required position. Now it must at once be apparent that the distance C′ A is too small, and the point C′ too ill defined to fix the position with that certainty we require. It has, however, been deemed advisable to introduce each of the methods upon the same bases as corroborations.

Thirdly, and Proof.

Extend the lines B D′ b and B D b' until they intersect perpendiculars raised on the extremities of the bases, (which will also be found to cut on the circumference of the circles). Draw the line b' b, and it should pass through the station, which line should be bisected at

right angles by a line passing through the centre station B. Hence then we have full proof, that in this case the station is satisfactorily determined.

We will now proceed to investigate this problem. No. 5 is repeated, divested of the second method, in order to render the observations more distinct.

First, then, the determination of the centres of the circles results from the complement of the observed angle, and the lines bisecting the bases.

And it must be evident that C, *b*, and A, *b*′, are lines parallel to those intersecting the bases, that the two great triangles so constructed are fully available, the three angles and one side being known. Thus, complement of observed angle 49° = angle at B = 41°, and 41° — 90° = 49° angle at *b*, (the base being at any point in the circumference viewed under the same angle,) that at C being 90°.

If, therefore, we determine the legs B, *b*, and B, *b*′, we can determine the angles in the other triangle, and obtain the direct bearing and distance of the required position, without cutting up our paper by a series of projections.

Thus in the triangle A, B, *b*′,

B = 47° 30′	As the sine 42° 30′ ar. comp. (*or Cosec.*) .	0·170317
b′ = 42 30 (observed ang.)	: Base 4′·01 . . .	0·603498
A = 90 00	: : Rad. . . .	10·000000
180 00	: B, *b*′, 5′,94 =	0·773815

	In triangle B, C, *b*, as sin. *b*. 49° 0′ ar. comp. (*or Cosec.*) .	0·122220
B 41 0	: base 5′·22 . . .	0·717322
b 49 0 (observed ang)	: : Rad. . . .	10·000000
C 90 0		
180 0	: B, *b*, 6′,91 .	0·839542

Then to obtain angle at B.

Side B, *b*′, 5′·94	A B *b*′ = 47 30	As sum of sides 12·85 ar. co.	8·891097
B, *b*, 6·91	C B *b* = 41 00	: Diff. of sides 0′·97 .	9·986772
		: : Tang. ½ sum of ∠s 63° 55′	0·310217
Sum 12·85	Sum 88 30		
	∠ B 140 40	: Tang. ½ diff. 8° 45′ 57	9·188086
Diff. 0·97		63 55 00	
	Included ∠ = 52 10		
	127 50	Sum = 72 40 57 *b*′ gr. or opp. gr. side.	
	½ sum of ∠s 63 55	Diff. 55 9 3 = *b* less or opp. less side.	

Therefore, as the line from B cuts that of b', b, at right angles, we at once resolve the question into two right-angled triangles, as follows:—

The angle at $b' =$	72° 40′ 57″	Then, as rad.	10·000000
At position x	90 00 00	: Side B b' 5′·94	0·773815
		: : ∠ b' 72° 40′ 57″	9·979853
	162 40 57		
		: B to x 5′,67	0·753668
Angle at B	17 19 3		

Now having the angle A B $b' = 47° 30'$
and b' B x = 17 19 3

A B x = 64 49 3
∠ at B = 140 40 0

C B x = 75 50 57

Consequently the lines of the bases being known as true bearings, that of the position results, which if material, would thence be reduced into difference of latitude and longitude, as will be hereafter noticed.

It is therefore preferable, in placing positions, to go through the foregoing calculations in preference to cutting up the paper by compasses, lines, &c.; and should it be advisable to project, let the stations be pricked through on another piece of paper, and apply the distances from it.

Frequently it will occur that the radius will be so extended that the paper will not admit of its being worked, or the compasses subtend the distance. This objection is met by the method described by Beautemps Beaupré. Thus in the diagram, plate III. fig. 6.

Let C A = 30° 00′ and A B 40° 00′, and angle subtended by the legs = 191° 30′.

First then, we have projected the position by the former method. The rule for the latter is as follows:—

Add together the observed angles, and subtract their sum from 180. At the centre station lay off these angles as C A E, B A E′; at C, lay off the angle A x B=40°; and at B, C x A=30°. Produce the lines B E′, C E to x, and the intersection will be found to coincide with the former.

This supplementary angle may cause the line to pass through x to E′ and E, but does not affect the principle. Thus in fig. 7, plate II. let C A be observed at 54° 15′, and A B 52° 45′ required x— ? x then occurs within the intersection.

In the former case it is evident that the position x is readily obtained, as the two bases and all the angles are given. That is, supposing as a matter of course, that the angle subtended by the bases be known.

In these examples the determination of the station x by calculation is rather circuitous, yet plain.

Thus the angles A E C and A E′ B respectively, are equal to their corresponding angles at x, being on the same segments, which is apparent on No. 6. The materials therefore are to be considered as follows: the bases, the angle contained between them 191° 15′, the supplement of the sum of the observed angles = 73°. The observed angles themselves.

We must first determine one of the sides, say A E′.

Then 191° 15′ − 73° × 2 = 45° 15′ + 73 = 118° 15′ = the included angle between the side found and A C. Then having the sides and included angle, determine the angles at C and E′. Now, as the line to E′ passes through x, it is evident this is the measure of the angle A C x, and the sum of this and the observed angle — 180° completes that triangle; whence, with the base A C, x is readily determined.

It is evident also that the other triangle is complete, as the angle C A x being known, and subtracted from 191° 15′, its adjacent angle results, which with the observed angle render both bases available.

The same method applies to both cases, although the legs are produced to the position instead of passing through, as in the latter.

As an example interests more, and induces reflection, we will proceed with the work in full for the latter problem, (fig. 7.)

Side B A = 3′,4		As the sine of E′ 52° 45′, ar. com. (*Cosec.*)	0·099086
		: Base B A = 3′,4	0·531479
		: : Sine B = 54° 15′	9·909328
		: A E′ 3′,46	0·539893
Then A C = 3′,65	191° 15′ whole ∠	As 7′,11 ar. co.	9·148130
A E′ 3,46	146 sum of supp.	: 0′ 19 diff.	9·278754
		: : tang. ½ sum. 30° 52′ 30″	9·776625
Sum 7,11	45 15 diff.		
	73 supp.	: tang. ½ diff. 0° 54′ 55″ =	8·203509
Diff. 0,19			
	118 15 included ∠ C A E′	30° 52′ 30″	
	61 45 = — 180.	31 47 25 opp. gr. side = E′	
	30 52 30 ½ sum required ∠s	29 57 35 opp. less = C.	

Now $\angle$ C = 29° 57′ 35″		Then, as 54° 15′ log. cosec	0·090672
x = observed	54 15	: Base A C 3′,65	0·562293
		: : 29° 57′ 35″ sine	9·698441
Sum	84 12 35		
		: A x = 2′ 24	0·351406
— 180 =	95 47 25 = A		

The preceding examples have not embraced angles exceeding 90°, we will therefore proceed to show how the projection would stand under such circumstances.

The excess above the rectangle is to be laid off on the opposite side of the base if the radius be made use of. It will exhibit a variety of position by the latter method, showing where E′ E may be thrown.

Let the angles observed be C A = 120° 30′, and A B = 30° 0′.

The centre of the circle C E A, &c. will be found to the right or opposite side of the base, and on such a small scale it may readily be imagined what the radius would have been had the bases extended over ten or twelve inches; E′ E in this case also occur on one side of the position x.

We will conclude this subject with one more example of Beautemps Beaupré, which will afford some idea of the length of radius which may be in some cases required, as well as point out his mode of projection.

Let the angle C B be observed at 41° 0′, and B A (fig. 8,) 14° 0′.

The segment B A x shows what the radius would have been in this figure, had it been necessary to make use of it.

The method, however, of Mr. Beaupré is neater, and more convenient. Thus, at C lay off A C E = 14°, and at A, E A C = 41. Through the intersection at E, draw the indefinite line B, b; at C, lay off the angle y equal to A E b, and where this intersects the indefinite line B, b, is the station required.

It is to be presumed that sufficient has been introduced to enable the young surveyor to proceed with satisfaction to himself, if he be disposed to investigate his work thus closely. But it should be borne in mind that *expedition is important*, and that the data once obtained, can at pleasure be investigated and corrected when weather hinders, or other circumstances, prevent further operations on shore or afloat. If attention be observed in taking the necessary angles, which in all cases

should be as near two right angles as can conveniently be obtained, the station pointer is sufficiently correct for any purpose connected with soundings.

Many there are who affect to reject the station pointer in toto, and conceive it almost a reflection that it is in the catalogue of instruments supplied. They trust, however, to the computation of another head, more liable to mistake than a *well-constructed* instrument in the hands of the principal, who can form his own opinions at the instant upon the value of the angles which he then *sees* projected before him. Stress has been laid on "*well-constructed.*" Those on the old construction are unwieldy, and in a late survey, so much out of repute, that the instrument was *entirely rejected*, and tracing-paper used instead. And so far did the persons engaged consider the want of the instrument as *important*, as to induce them to think of supplying the deficiency at their private expense.*

We will suppose that a landing was effected, the chronometers rated afresh, and the ship again starts on her voyage. Ten days after departure, by a series of astronomical bearings of some object, which has been sufficiently above the horizon, it is found that the chronometers are performing well. The ship on her passage has to pass some dangerous shoals which are connected with the land, but which is too distant to be made out. The observations prove these shoals to be laid down many miles erroneous in longitude, and it is advisable to survey them, and carry on this survey to the land. Under such considerations, vessels fitted for surveying only could conveniently complete such a work, and therefore, as the operations would be the same, continued from day to day, without removing the stations at night, we will proceed with such materials presently. At the same time, however, it will be shown how a frigate, with her establishment of boats, could make a very fair flying survey of ten miles square between sunrise and sunset, provided she fits two beacons.—(*Vide* plate and description.)

As we are assuming, in this proceeding, that we are in a ship of war *not expressly* bound on surveying duties, we shall proceed. The time in which this service (that is, the single shoal) must be completed, will be during daylight, as the boats crews cannot remain exposed during the night. A frigate's establishment of boats consists of—launch, barge, pinnace, two cutters, gig, and jolly-boat. We suppose that

* The survey conducted in the Etna was almost exclusively conducted by private instruments.

the discovery of the shoal was made in the afternoon, and that the ship immediately anchored—sent her boats to sound, to ascertain the safe direction for egress—and finding her position enabled her to move (if required) without danger, determined on the survey of the bank. The first object is to moor in the direction of the current, or tide, and rather taut, to bring the anchors well into the ground; hoist out the boom-boats, and give the launch her carronade. The officers to take the command of the various boats to provide their equipments:—compass and requisites for light, arms, leads and lines, anchor and cable, water baréca, (a list of which should always be in the watch-bill, and are necessary in all guard-boats, which should be supposed prepared to render assistance.) The provisions prepared for each boat, so that when daylight arrives, no delay may be experienced. Some one must assume the *direction*, the captain if possible, and the orders should be *distinct*, and such as may not only answer on this *immediate* question, but which may serve as the model for all others, and which might be taken for a "fleet survey," if such should be required. At daylight heave the riding cable taut. In issuing the orders, bear in mind that the courses on which you send each boat should be such, as shall not only carry them to their *intended* positions, but accommodate your paper, as will shortly appear. You have seven boats, these boats eventually will occupy positions from North by the East, to South, at 30° asunder. At once, then, the radii are determined without trouble. A base of five miles is quite long enough. Let the gig proceed North, true; (give the courses corrected for variation;) the second cutter N. 60° E.; first cutter S. 60° E.; jolly, S. The launch, with her carronade, to accompany first cutter. The orders to these boats, as follows—when the estimated distance (estimate by ball at truck, previously computed with height of mast as base) is attained, look out on launch (the officer of which boat will superintend the mooring of first cutter, and eventually command her.) The instant the first cutter shows the signal for being *moored*, the second cutter and jolly-boat will take up their positions, on their bearings, at not less than an angle of 60° between ship and first cutter. Thus the two main equilaterals are fixed. (*Vide* Plate V.) When the second cutter shows her signal the gig will also take her position.—(*Vide* Orders.) These boats, then, occupy the main positions, and should be taut moored *with the stream*, and a ship's flag hoisted on a long boat-hook staff on the foremast by

the boat's halliards, which will at least carry it twenty-five feet above the horizon. The courses for the barge and pinnace will be, barge E., pinnace N. 30° E., and they should be instructed "to anchor when they have attained the distance of five miles on their directions," that their soundings may be available, (should not uneven ground have occurred before, in which case they would of course anchor instantly.) The main stations, then, being fixed, the barge and pinnace proceed on their courses until their bases subtend an ∠ of 60°, endeavouring to get the ship equidistant between them; they will then moor, and endeavour to obtain the measurement of their distance by sound. The ship, when all have moored, should hoist the ensign at the fore. Dip it when the boats have answered, and hoist when *about to* fire, the motion of the flag *going up* giving much better warning than dipping. The gun should have its greatest elevation, that the column of smoke may be clearly perceived by those in the distance, and shotted gives a smarter report. Those in the boats who are to measure, will of course compare their watches with the chronometer, and ascertain the number of beats their watches make.

[Good watches and pocket chronometers beat five to two seconds. Practice will enable the division of the beats.] Three guns should be fired by the ship, three by the launch. We shall then have the following bases—

Ship,—First Cutter, probably pinnace.	First Cutter,—Barge.
Second Cutter.	First Cutter.
Gig.	Ship.
Jolly.	Jolly.

making eight certain, two uncertain, equal to twenty-four measurements.

The launch will then proceed south of first cutter, and take up her position on that bearing at an angle of 60° between first cutter and jolly, and 30° first cutter and ship. When she is moored, the cutters will weigh, and proceed with their beacons on their own lines of bearing, and place them; the N. at angles of 60° each, between pinnace and ship, ship and barge, the S. = 60° barge and ship, ship and launch. When the last gun is fired the gig will be released, and will proceed sounding as directed. When the launch is moored, the jolly will do the same; and when the beacons are moored, the cutters will also. It will now be apparent, that extended bases of nine miles have been procured; that the ship, barge, pinnace, and launch can

display flags far above beacons,* (which I have *reflected* at nine miles in warm climate, flag and observer being only twenty feet above the sea level,) and that four boats are free to sound, which is a wide survey; but should it be found necessary to resume it the next day, mark the cables, buoy them, leave the beacons, and simultaneous angles only, will render its continuation simple.

Supposing, then, the above observations have been acted on, we will now examine the data which would thus be procured, and if it appears that the student in surveying can put his work on paper, will it not then prove the value of such documents to the Hydrographical Office? Thus then the materials will stand.

June 4th, 1832.—At 4·30 P. M. steering south with wind at north-west, found the water suddenly shoal to seven fathoms; hauled to to the westward, shoaled to five, water discoloured a-head; shortened sail and anchored in five fathoms, out boats to sound; found water deep to the westward, and nothing less than five fathoms within a mile and a-half of ship. As this danger is not placed on the chart, determined to make a survey, satisfied that from the season and latitude, no winds but those from the eastward blow strong, and sufficient warning is given. Moored, prepared boats, and fitted two beacons.

June 5th, 1832.—At daylight boats left the ship, the launch taking her carronade.

Mean cor. to A. T.						Dec. Cor.
Ship at 7 10 5,3	⊙	20° 14′ 45″	⊙ 1 cut.	5° 20′ 35″		22° 34′ 18″
1 cutter moored.	⊙ Semi. di.	15 47	⊙ Semi. di.	15 47		
					Pol. dis.	67 25 42
		20 30 32		52 16 22		
	Dip	3 41				
		20 26 51				
	Ref.	3 6				
	T. alt.	20 23 45				

We will therefore proceed immediately to determine the true bearing of the first cutter, or main base. Every epitome of navigation contains rules for determining the true bearing of the sun, as connected with the variation of the compass; but in one only have I

* Two, or four, watering casks may be supplied for this purpose with double staves at bung and opposite, and will be always ready for use. (*Vide* description and diagram.)

met with the method in combination for determining it by reference to a headland; that is in Professor Inman's, which is in general use in the profession, but his omission of his 10″ differences, in the last edition of his Tables, is to be regretted. We cannot do better than repeat his rules, or rather formulæ, taking it for granted the book will be at hand, and that it is needless to repeat the necessary corrections. Thus,

Lat.	11° 25′ 10″ N.	= Sec.	0·008683
True alt.	20 23 45	= Sec.	0·028118
Difference	8 58 35		
Polar dist.	67 25 42		
Sum	76 26 17		
Diff.	58 27 7		
½ sum	38 13 8·5	= Sine	9·791457
½ diff.	29 13 33·5	= Sine	9·688647
		2)	19·516905
½ arc.	34 59 14	Sine	9·758452

App. alt.	20° 26′ 51″	= Sec.	0·028264
App. dis.	52 16 22		
Sum	72 43 13		
Diff.	31 49 31		
½ sum	36 21 36·5	= Sin.	9·772951
½ diff.	15 54 45·5	= Sin.	9·438021
		2)	19·239236
½ arc	24 36 50·5	= Sine	9·619618
Hor. ∠ =	49 13 41		

⊙s true bg.—N. 69 58 28 E.
Hor. ∠ + 49 13 41 = object right of ⊙.

119 12 9

— 180 = S. 60 47 51 E. true bearing of 1st cutter.

A shorter method of obtaining the above is,

App. dist.	52 16 22	Cosi. + rad.	19·786688
App. alt.	20 26 51	Cosi. =	9·971736
Hor. ∠ =	43 13 39	Cosi. =	9·814952

Let us now see what the time would give as a check on the others.

7h 10′ 5″, 3 app. time as deduced from chronometer.

4 49 54, 7 time from noon.

2 24 57, 85 = ½ hour ∠.

Lat.	11° 25′ 10″ N.				
Co. lat.	78 34 50				
Pol. dist.	67 25 42				
Sum	146 0 32				
Diff.	11 9 8				
½ sum	73 0 16	Cosec.	0·019393	Sec.	0·534175
½ diff.	5 34 34	Sine	8·987523	Cosine	9·997940
½ hour ∠	2 24 58	Cotang.	0·134936	Cotang.	0·134936
1st tang.	7 53 33 =	Tang.	9·141852	Tang.	10·667051
2nd tang.	77 51 8				
☉'s true bearing	69 57 35				
	69 58 28 by alt.				
Diff.	0 53″				

Thus far then the true direction of the base is determined. The boats are in their stations, and the guns have been fired to determine the distance. We will suppose the results to run as follows:—

SHIP'S GUNS.

	At 1st cutter	2nd Cr.	Gig	Jolly	Barge	Pinnace
	66 beats	68	67	66	117·5	117
	67	67·5	67·5	67	118·5	118
	66·5	68·5	67·5	66	119·5	117·5
Means	66·5	68·0	67·33	66·3	118·5	117·5

BOAT'S GUNS.

	At ship	2nd cutter	Barge	Jolly
	66	68·5	69	66
	68	68	68·5	66
	66	68·5	68·5	66
Means	66·7	68·33	68·7	66

As the main base is what we require for immediate use, we will revert to it at once, the others may be worked out at leisure, and a mean reduced to every side of a triangle thus measured. Such nicety is not at present required, and we suppose the best observers employed on the main. Thus,

From ship to 1st cutter . . .	66·5
1st cutter to ship	66·7
Mean . . .	66·6

And allowing five beats to two seconds, or 456,8 feet to each beat, we have 456,8 × by 66,6 beats = 30422,88 feet, which divided by 6075,6 feet (or nautic mile) gives 5′,007 miles (or 45 feet above five miles.) Thus, then, we lay off on paper the base from the ship to the first cutter S. 60° 48′ E. (as the protractor will not measure seconds,) five miles, which is as close also as this work will call for. If latitude or longitude be involved, the pertinent question will be—Who determines it to this accuracy afloat?

The ship's deck-book is next to be called in aid.

Depth at 4 A.M. 5½ ebb-tide just made to S.E.; rise and fall during the night 9 feet 7 inches. Moon's age, 26 days.

At 7 observed 1st cutter make signal for having moored in position.

7·5, 2nd cutter, gig, and jolly, moored.

Time — 7 h. 10 m. 5·3 s. — 20 14 45 — ☉ object first cutter 52° 0′ 35″, by mean of five sights. No index error.

∠s taken; jolly and 1st cutter . . . . . 59° 47′ } 61° 5′
2nd cutter . . . 120 52 }
2nd cutter and gig 58 33
8.40, barge moored; 1st cutter and barge . . . 30 15
9, pinnace moored; 2nd cutter and pinnace . . 29 8

Made signal to prepare to measure base by sound. Fired 3 guns. ∠s not altered.

Launch fired 3 guns close to cutter's bow. First report, 66 beats; second, 68; third, 66.

10, Launch proceeded to station.

Gig weighed, and proceeded sounding.

2nd cutter ditto, and proceeded with beacon.

11.10. Launch moored, ∠s launch, and 2nd cutter . . . 30 12
Jolly and launch . . . 29 35

Jolly weighed per signal, and commenced sounding.

12. Noon, Latitude by mean of best observers on board, 11° 25′ 10″ N.

12.40. N. beacon moored. Beacon and pinnace . . 29° 3′
Barge and N. beacon . . . 33 12
12.50. S. Do. Do. ∠s launch and S. beacon . 30 12
Beacons 61 25

2. Observed 2nd cutter and gig at anchor, and danger flags displayed.

∠s, barge, and S. boat (gig) . . . . . . 23° 5′
N. boat (2nd cutter) 41 8
2.20. Do. repeated N.E. boat (cutter) . . . 33 15
N.W. boat (gig) 31 55

FIRST CUTTER.

(Red Beacon.)*

June 5th, 1832—Left ship at 4. 50, steering S. 60° E. or S.E. by compass. (Var. 15° W.) Water alongside, 5½; by boat's line, 5½. No correction. Fall of tide 9 feet 7 inches.

4 sand . . 4½ . 4½ . . 5 mud . (5 h.) . . 5½ 5 . 4½ sand (5. 10) . . . . . 4½ — (5. 20) . . . 4 . . (5. 30) . . 4 . . 4½ . . . 4 (5. 40) . . . . 4½ . . (5. 50) . . . . 4 . (6) . . 4½ . . . . (6. 10) . . . 5 . . . . (6. 20) . 5½ . . . . . (6. 30) . . 5½ . . . (6. 40) . . . 5½ mud . . (6. 50) . . .		
Moored and made signal.		
Observed 2nd cutter moor. ∠ 2nd cutter and ship	60. 30	59. 43
Jolly moored. Jolly	120. 13	
7. 10. Barge moored. Barge and 2nd cutter..........	60. 0	
Ship	120. 30	
Ship made signal, "prepare to measure base," and fired 3 guns.		
1st, 66 beats; 2nd, 67; 3rd, 66. 5.		
Launch fired, and proceeded to position.		
11. 30. Launch moored. ∠s Ship and launch	119. 20	
Jolly and ditto	*59. 37*	
Jolly weighed per signal; weighed and stood on to S.E.		
(11. 50) 5½ sand . . . . 6 mud . . (12. 0) . . . 6½ 6¾ (12. 20)		
6¾ ∠s Barge and ship	101. 23	
Ship and launch	99. 0	
6¾ . . . 7 . . (12. 30) . . 7½ . 7 sand . (12. 40) 6. 5 rocks, ∠s.		
5 fm. ∠s. Same objects	82. 30 79. 47	
(12. 50) 5 sand . . 4½ . . . . 4 . . (1. 0 h.) . 4 . . 3½ sand . 3 rocks . ∠s.		*(Mem. principal.)*
∠s 3 fms. Same objects	71. 40 69. 35	*Should have taken barge and ship* 61·33
(1, 10) . 3 sand . . 3½ . . 4 . 4½. Placed beacon 4 fms. sand.		*B. & L.* 121·15
∠s 4 fms. (S. beacon) Ship and launch	59. 42	
Barge and ship	61. 33	59·42
Continued sounding. (Ret. 5. 40.)		
(Signed) W. B.		

* The names coinciding with Plate VI. have been introduced within parentheses.

SECOND CUTTER.

(White Beacon.)

une 5th, 1832—5. Left ship, steering N. 60° E., or by compass N. 75° E. Water alongside, 5½ ; by boats line, 5¼, add ¼. Fall tide, 9 ft. 7 in.

4 . . . . . (5.10) . 4½ mud . . 5 . . . (5.20) 5¼ . . . . . . (5.30) . 5½ . . . . 5¼ — (5.40) . . . 5 . . . . . . (5.50) 4¾ . . . . . . (6.0 h.) 5 . . . . (6.10 . . . 5¼ . . . . (6.20) 5½ . . . . . (6.30) . 5¾ . . . . . . (6.40) 6 . . . . . 6½ — (6.50) . . . . . . 7 mud . Anchored—moored at (7.10.)		
Gig and 2nd cutter moored.		
∠s in position, 7 fm. mud. Gig and ship	60.10	58.25
1st cutter ..	118.35	
(9 h.) Pinnace moored. Pinnace and gig......	61.15	60.10
Ship..	121.25	
Observed barge moored. 1st cutter and barge ..	60.10	
Barge and pinnace	120. 5	
9.30. Ship made signal, "prepare to measure base," and fired 3 guns.		
1st, 68 beats; 2nd, 67.5; 3rd, 68.5.		
9.50. Launch fired 3 guns.		
1st, 68.5; 2nd, 68; 3rd, 68.5.		
Obsd. gig weigh; 10 weighed and proceeded with beacon.		
7 . . . . . . (10.10) . 6 sand . . 5 . . (10.20) 4½ . . 4 rocks . . . 3½ rocks.		
∠s 3½ fms. rock. Pinnace and ship	96.38	
Ship and barge	93.00	
3½ . . 3¼ sand . . . (10.30) . . 3½ . . . . 3 rocks dry, 2 3.		
∠s 3 fms. near rocks, dry low water.		
Same objects	76.00	
	73.48	
On to beacon 2 3½ . 3 . 3½ . (10.50) 4 . . . 4½ . . . 5 . .		
Placed beacon. ∠s 5 fms. Pinnace and ship	59.37	58.43
and barge	118.20	
On for N. extreme of shoal, 5 . . . . 4 . . . 4½ . 4 (11.10) . . 3½ . . . . . 3 rocks . . . . . 2½ 2.½ fast to rocks; made signal.		
Pinnace and ship................	94.15	
Ship and barge..................	74.45	
Barge and gig at anchor..........	10.32	
N. beacon	61.43	
Beacon and pinnace	129.17	
At 2nd position. Gig, mark, and B in line—round of ∠s repeated.		
(Signed) H. H. W.		

GIG.

June 5th, 1832—Left ship at 5 h. steering north. (N. 15° E. by compass.) Water alongside 5½; same by boat's line. Fall of tide, 9 feet 7 inches.

4 . . . 5 . . . (5.10) . . . 5½ . . . 6 mud . . (5.20) . . . . 6¼ . . 6½ (5.30) . 7 . . . . (5.40) . . 7½ . . . . . (5.50) . 8 . . . . (6.0) . . . . . 8½ 9 (6.10) . . . . . . 10 . . . (6.20) . . . 10½ . . . (6.30) . . 11 . . . . 11½ . (6.40) . . . . 12 . . . . . (6.50) . . 12 . . . . . . (7.0 h.) Anchored. 2nd cutter moored.		
Ship and 2nd cutter	61.17 } 60.15	
Pinnace moored. Pinnace	121.32	
Ship made signal, "prepare to measure base," fired 3 guns. 1st, 67 beats; 2nd, 67.5; 3rd, 67.5.		
Launch fired—1st smoke, 2nd do., 3rd do.—No report to judge by.		
10.10. Weighed, as did 2nd cutter . . towards pinnace — 12 mud . . . . . 12½ . (10.20) 12½ . . . . (10.30) 12 . . . . . 12½ (10.40) 12½ . . . . (10.50) 13 . . . . (11.0) . . . 12½ . . . . . (11.10) 13 . . . . passed pinnace (11.20) towards N. beacon (moored)—12½ . 12 . . (11.30) 10 . . 8 . . 7 (11.40)		
∠s 7 fms. Pinnace and ship	65.50 } 62.22	62.22
Barge	128.12	43.48
N. beacon	43.48	
Observed ripplings S.W. stood for do. 6 sand . . . 5 . . 4 . . . passed cutter and desired her to anchor on N. limit — stood on — 4 . . 3½ rocks . 3 . 3½ 4, 3½ 3 . 2 . 3½, 4 . . 3½ . . 3 . . 2 . . 1½ . . 1 . ½ dry—made signal on S. extremity.		106.10
Took position, flag on rocks, 2nd cutter, and pinnace in line. ∠s South extremity reef ...... { Pinnace and ship......	75.52	75.52
Ship and barge.........	84.55	84.55
Barge and beacon	134. 0	134. 0
Beacon and pinnace ...	65.13	65.13
Towards N.W. for west extreme, under 1 . . . at S.W. ∠ of reef.		360. 0 *good.*
Pinnace and ship............	93.15	93.15
∠s at S.W. extreme. Ship and barge	88.45	88.45
Barge and S. tang. reef	27.45	88.20
Beacon and 2nd cutter 91.10 { N. beacon............	88.20	89.40
W. tang. reef 75.45 { Beacon and pinnace	89.40	
Passed round westerly — 1½ . 2 . . 2½ . 3 . . 3½ . 5 . . .		360. 0
∠s 5 fms. (sand) Pinnace and ship	127.28	
Ship and barge.........	76.15	

GIG—*continued.*

To N.E. — 5 sand . . . 4½ rocks . . 4 . . 4 . . 5 . 6 mud 7 . . 8 . . 9 . . . . . 10 . . 10½ 11.		
Pinnace and ship........	51.18	
∠s 11 Ship and barge..........	55.13	
N. beacon......	71.53	
To N.E. ? ripples 11½ . . 10.		
7½ . 5 . N. beacon and barge in line — ∠ to pinnace ..	95. 0	
5½ . 7 — 9 . . . . 9½ . 7 . . 6 . 5 at beacon.		
Pinnace and N. extreme, reef dry..........	26.40	
S. do. do.	90.22	
On, keeping beacon and pinnace in line, 5 sand . . . 6 . 7 sand . (3.0 h.) . 7½ mud . 8 . . . 9.		
∠s 9 fms. mud. Beacon and pinnace in line ∠ to barge..	85.45	
To ship — 9 . 8 . 7½ . . . . (3.20) . . 7 . . . (3.30) . 7¼ . . . 7 . . . . 6½ . (3.40) . . 6 . . . . . (3.50) . .		
∠s 6 fms. Pinnace and ship	72.33	
Ship and barge	85.45	
(4.0 h.) 6 . . 5½ . . . (4.10) . . . . 5 . . . 5 . . . (4.20) 5 sand . . 5		
∠s 5 fms. Barge and pinnace......	114.45	
Pinnace and ship	106.25	
5 . . . . (4.30) . 4½ . . . . . (4.40) . . 4¼ . . . . (4.50) . . 4 . . . . . . At ship, 5 h.		
(Signed) H. S. S.		

Note. The foregoing are sufficient in practice; but I have had frequent cases of 46 angles, each boat with zealous officers, and the ground well cut up. We cannot omit the stations. We will, therefore, give the other boats without their soundings.

JOLLY.

Quits under similar formula.

At her station—observes. Ship and 1st cutter moored ∠ 1st cutter and ship	60.30	
Launch moored. Launch and 1st cutter	60.10	
and ship	120.40	
For base. Ship's guns—1st, 66 beats; 2nd, 67; 3rd, 66.		
Launch—1st, 66; 2nd, 66; 3rd, 66.		
Weighs and proceeds sounding, returning to ship at 5.		
(Signed) H. H. B.		

Thus far, then, we have the angles for the sounding boats, which would have traversed the lines as noted, (and would be indicated

by the orders.) In returning, the pinnace would sound to beacon, weigh it, and return to ship. The barge the same with the south beacon. We will now finish the data with the angles of the station boats.

PINNACE.*—(2 B.)

Same formula as gig and others—Soundings omitted.

∠s observed at station. 1st cutter, gig, and ship moored.		
Gig and ship	29.13	58.30
Ship and 2nd cutter..	29.27	
N. beacon moored (12·40) Beacon	91.20	
At 2h. 2nd cutter and gig hoisted danger flags, *objects in line.*		
Ship and *objects in line*	67. 5	
2·20 boats shifted. Ship and 2nd cutter..	74.00	
Gig........	58.40	
Boats continued sounding, 5 proceeded to N. beacon—(soundings omitted)—and on to ship.		
Observations for base. Ship's guns. 1st, 117·5 beats; 2nd, 118·5; 3rd, 119·5, launch not made out.		
(Arrived at ship 7h. 5′.)		
(Signed) J. H.		

BARGE.—(1 B.)

Same—Soundings omitted.

Moored in position 8·40. 1st and 2nd cutter and ship moored ∠s. 2nd cutter and ship	30.35	
1st cutter..	59.50	
Ship's guns, 1st, 117.5; 2nd, 118·5; 3rd, 119·5.		
Launch; 1st, 69; 2nd, 68·5; 3rd, 68·5.		
Observed N beacon moored. ∠s N. beacon and ship..	88. 5	
S. do. do. Ship and S. beacon..	90.15	
Observed gig and 1st cutter with danger flags displayed.		
∠s — N. beacon and gig (at S. extremity)..	18. 5	
2nd cutter (N. do.) ..	26.10	
Boats shifted positions to N.E. and S.W. extremities.		
∠s N. beacon and 2nd cutter....	18. 5	
Gig..........	30.38	
Boats continued sounding.		
At 5 proceeded to S. beacon, weighed do., and on to ship. (Soundings omitted.)		
(Arrived at ship 7·20.)		
(Signed) J. H. G.		

* See Plate VI.

LAUNCH. (△)

Same—Soundings omitted.

At position S. 30° E. (true) from ship. 2nd cutter, ship, and jolly moored.		
∠s 1st cutter and ship....	30.28	
Jolly ...	60.13	
S. beacon moored. S. beacon and ship....	89.58	? E. B. 8′ too small.
At 5 sounded to ship. (Soundings omitted.)		
Arrived at (7·20.)		
(Signed) G. H. W.		

Here then, if fairly filled in, are documents which are of importance, and can easily be referred to paper, bearing in mind that the eye sketches of the conformation of the reefs, their nature, &c., will naturally be looked for.

We will proceed to lay down the materials we have obtained, with this observation, that to the beginner too many lines of soundings would confuse the plan—*part* of three boats' operations only, will be used; but as a peculiar line will be used for the track of each boat, it will be seen what can be done by the resources we have had at command.

We could at once proceed to work without further examination, but cannot lose sight of the very essence of this service, viz. *method.* Let us be assured that the documents with which we have been supplied are capable of being laid down, and reject those which may be faulty, thus moving one step towards avoiding useless lines and retaining clean paper.

We have obtained six *main* nearly equilateral, and four subsequent right-angled triangles. We will take them in succession as formed—

1st. Ship	∠ 2nd cutter and gig	58.33	2d. Ship,	Cutters . .	61.5
Gig,	Ship and 2nd cr.. .	61.17	1st cr.,	2nd cr. and ship	60.30
2nd cr.,	Gig and ship . .	60.10	2nd cr.,	Ship and 2nd cr.	58.25
		180.0			180.0
3d. ship,	Jolly and 1st cutter .	59.47	4th. 2d cr.,	1st cr. & barge	60.10
Jolly,	1st cr. and ship . .	60.30	Barge,	Cutters . .	59.50
1st cr.,	Ship and jolly .	59.43	1st cr.,	Barge and cr.	60.0
		180.0			180.0

5th. 2d cr.,	Pinnace and gig	. 61.15	6th. Jolly,	Launch and cr.	60.10
Gig,	2nd cr. and pinnace	60.15	1st cr.,	Jolly & launch	59.37
Pin.,	2nd cr. and gig	. 58.30	Lau.,	1st cr. & jolly	60.13
		180.0			180.0

Having thus far proof that all is correct, and being satisfied that our extended bases—ship, pinnace, barge, launch—are correct, let us examine how the beacons will stand the test.

1st △ ship.;	Beacon and pin.	29.3	2d. △ ship;	Barge and N. beacon	33.12
N. beacon,	Pin. and ship	. 59.37	N. beacon,	Ship and barge	. 58.43
Pinnace,	Ship and beacon	91.20	Barge,	Beacon and ship	. 88.5
		180.0			180.0

3d. Ship,	Beacon & barge	28.12	4th. Ship,	Launch and S. beacon	30.12
Barge,	Ship & beac. S.	90.15	Launch,	S. beacon and ship	. 89.58
S. beacon,	Barge & ship	. 61.33	Beacon,	Ship and launch	. 59.42
		180.0			179.52
				Error	8

The launch, therefore, has made an error of eight minutes in her angle, as all the others stand the test. We now proceed to paper. A common sheet of double elephant will clear about two feet by three. This is not too large for the purpose; one inch to a mile is sufficiently large for these surveys, and at sight it will appear that the meridian base occupies fifteen miles, and it may be advisable to extend it. In the centre of the sheet, draw the meridian nearly parallel to the edges of the paper, and on the centre of this raise the perpendicular, or parallel; at the intersection place the ship's position (as in Plate V.) [N.B. If a two-inch scale be required, draw the meridian through the length of the paper, which will leave three inches clear of each station.] Lay the protractor on the meridian, and lay off the true bearing of the first cutter as computed = S. 60° 48′ E. If no protractor be at hand, by the scale of chords, as described in all works on geometry.

Draw a line through this, and with your compasses lay off five miles, equal to five inches (if that be the scale you have determined on.) Your main base is then complete. From the true bearing of first

cutter lay off jolly, launch, S. beacon, barge, second cutter, N. beacon, pinnace, and gig, and draw lines through the points so laid off.* Then shift the protractor to the first cutter's position, (or that you have already measured, five inches from the ship's.) From that line lay off second cutter, barge, launch, and jolly; draw lines through the points, and where they intersect those from the ship, mark as the positions. These will be, second cutter, barge, launch, and jolly. Having fixed the position of the second cutter, transfer the protractor to it, and using the line *from the ship*, lay off gig, pinnace, barge, first cutter, and complete the stations intersected. The gig and jolly's positions being now determined, lay off from them similarly, the pinnace and launch, which were not before sufficiently fixed, from the smallness of the angle. The beacons only remain to be completed. Their position will be determined from the pinnace, (the lines already drawn from the ship,) the barge, and launch. Thus then, the stations are fixed, and we are now to turn to the sounding boats. The gig, we will suppose, carries the principal, although he ought to have been at one end of the base; we therefore commence with his report. He takes two hours to gain his position, (and by bearings frequently taken by the person appointed on board, all the boats were observed to have proceeded nearly in a straight line to their positions,) the soundings are found very regular. According to instructions, he has "noted the time every ten minutes." We therefore make twelve equidistant pencil marks on that line, and place the depths noted at his ten minute intervals, filling the spaces as appear by his notes. This completes the line to his position. He then proceeds on to the pinnace, under the same rule. Had he met with shallow water, he would, as he had no third object in sight, have anchored and made a signal, which would have enabled the ship and pinnace to fix his position, without the single angle he would take between them. He then moves on towards the beacon, until he observes ripples, and finding the depth decrease suddenly to seven, he immediately takes two angles, which enable him to fix his position. The station pointer here would fix it immediately, by laying off on the right leg, (holding it with the graduation upwards and the legs from you,) the angle, pinnace, and ship 65° 50′, and ship and barge 62° 22′,

* When any such lines are extended, and angles are to be laid off on them, it is important to *accurate projection* that the *original* line be ruled sufficiently long to admit of the protractor being applied to it, without being compelled to produce (or extend) it, as two lines can seldom be accurately drawn over each other, and a double line confuses.

on the left, but as we have another which approaches nearer to 180°, which will be truer, (106° 10′ ship and beacon,) it will be preferable to use it.

Supposing, however, we have not a station pointer on board: a simple substitute is to lay off the angles on tracing paper. Thus, draw a straight line from a point; on the right lay off, pinnace and ship, on the left, ship and beacon; pass the paper over the stations until they will not bear moving off the lines; a pin through the centre from which these angles were set off marks the spot. It then occurs, we have no tracing paper. Take a clean sheet of foolscap, lay off the angles as directed on tracing paper: with a ruler and penknife cut cleanly through the middle line to within half an inch of the centre, and cut the outer sides clean to the centre, which will then be a point, or, *if very obtuse, should be slit on the line one-eighth of an inch.* Apply this as directed for tracing paper. Failing in this we must refer to geometry, or calculation; but as we wish to preserve our paper as long as we can, lay a sheet of foolscap under the plan, and prick through the stations taken. Then proceed as explained in geometrical problems, and transfer the position found to the fair plan.

The gig then proceeds to the reef, desiring the cutter to station herself on the north end; fixing on the cutter and pinnace *in line*, to make sure of the pinnace taking him as well, (even should the pinnace fail to see him;) both boats take their round of angles, and then take up a second position, the gig leaving a mark (probably a handful of lime) on the top of the rock. [Mem. In whiting a spot much time is frequently saved by first wetting the spot well, and then dredging it on by hand. It stands better, and less is lost by *streaming* off—the thickness can be laid at pleasure, and is *instantly white.*] As the observations from the ship, barge, pinnace, and beacon, cut so exactly, the angles taken by the boats are superseded. Yet it will be as well to suppose the ship missed them. We shall still have the barge and pinnace, which in each case affording two angles, the third is naturally obtained by subtracting the sum of the two from 180, which gives that of the ship. Had the angles been taken by the boats only, the position in the *rough survey* would have been placed as the soundings are, viz. by station pointer, or geometry, and before they were received for use at the Hydrographical-office, the triangles would have been computed. When two stations can be brought in line, and a single angle taken to a third, (as when the gig passes outside of the triangles and gets N. beacon and barge in line

∠ 95° to pinnace,) the determination is very satisfactory. Thus, extend the line to where it is probable the boat was—lay off the angle. With the parallel rule (or triangle) applied to the angle laid off, move it until it meets the objects, draw a line, and the intersection must be the station. One angle on the station pointer, tracing paper, or cut paper, will illustrate this clearly. The gig again takes advantage of the beacon and pinnace in line ∠ 85°·55′ to barge. Her subsequent angles require the tracing paper or station pointer. These have been introduced sparingly, for the purpose of showing *how* they are to be laid down, and for practice.

In such a survey each boat would perhaps have 50 angles during the day: about every half mile, and in shoal-water frequently at every 50 or 60 feet.

It will hardly be thought that in the work exhibited, and twelve hours only employed, the boats have traversed 185 miles of ground, and sounded 160; yet this is to be done without extraordinary exertion, provided the officers commanding the boats have but moderate ability. It is not to be presumed that all this period the men are at their oars. Frequently only two hours in the forenoon, and perhaps the same in the afternoon: if the boats are fitted for sailing, they may be even the whole day under canvas. In continuous survey it is one of the principal points in framing the orders, to meet wind and tide, so that the least labour may fall on the men. Let those who think the work we have now been treating of, intricate, imagine what additional strain must press on the brain of one, who having already worked fifteen hours in the sun, (in 10° N. lat.) six by candle-light, putting the evolutions of seven boats, four vessels, and four beacons, on paper, has then to sit down at two, A.M. to the task of drawing out the motions of fifteen objects, subject to the capacities of seven assistants. This to meet winds, tides, and keep each traverse thoroughly distinct and independent, and without flagging the zeal of those concerned.

Having put on paper the stations, soundings, and reef, the next point is to put it into form. Many puzzle themselves too much about this before the work is finished. When the plan is completed it is high time to think of putting it into form. As before observed, the rough work is what is *required* at head-quarters; but for practice, let it be brought into further shape, and a reduced copy made. (The plate is half-inch.)

In reducing plans, the custom is to square off the original, (say to inches,) and the paper to which it is to be transferred to the propor-

tional. Thus, a quarter of an inch would reduce the plan to that scale. This outline is then reduced, by proportional compasses and eye, into the smaller divisions. As the reduction of the main tangents of islets, points, &c. is *important*, it is preferable to draw lines from the angles of the *squares* to the opposite side, so that no tangent can be thrown out, and taking the *distances where these lines cut*, lay off similar lines on the reduced plan, *within* which lines the object *must* be *confined*.

Now, originally, the meridian was drawn through the spot where the ship is placed. We will naturally suppose that the latitude and longitude has been scrupulously determined by equal altitudes from 8 A.M. until 4 P.M.; and that these data are ready for the chart.

The lat. is 11° 25′ 10″, that is, 10″ above the 25′ on the meridian. Find the meridional difference of lat. between 11° and 11° 30′

11° 0′=	664·09
11·30	694·68
Diff.	30·5

that is, 30 inches and six-tenths in 30 miles, or 5′ = 5,1 on the scale, 1 = 1,02. Take this 1,02 in. from the scale with the proportional compasses at the division 6, which will give on the reduced legs = 10″; or you may lay it off, and divide it into 6, if no proportionals are at hand. (The parallel divisions on the scale, as suggested in plate I., meet this instantly.)

Lay off this distance below the ship's position; you then have the division 25′; lay off 5,1 inches equally above and below this point, as far as the paper admits. Now, the extent required for this projection comprises seven miles and a half, N. and S. of the ship. Allowing two inches and a half clear of the stations, we shall obtain 11° 15′ 0″ and 11° 35′ 0″. At these points draw lines at right-angles to the meridian. Now, we assume that the longitude as determined by the chronometer is 17° 0′ 45″ W. The inch division is that of longitude, and 45″ = three-fourths of an inch: lay three-fourths of an inch off to the right of the meridian, on the top and bottom parallels, which were drawn through 15′ and 35′; that will be the 17th degree; graduate the inches right and left from it. The proportion in which appearance is concerned, is 20′ in latitude to 30′ in longitude.

If, therefore, we measure 15 inches east and west, of the last meri-

dian drawn, we shall embrace from 16° 45′ 0″ to 17° 15′ 0″; draw the meridians in ink through each 5′ of latitude and longitude, and complete the graduation.

The method here adopted is that proposed for an *extensive rapid survey.* If the radii only had been sounded off, and by a return on the intervals, thirteen lines of soundings would have been obtained in a loose manner; but here we have undoubted proof of the work, the reef outlined, and accurately laid down. This figure is intended chiefly to show the principle of rapidly extending bases. Had the operations been those of a "surveying vessel," the beacons would have been placed in the cutters' first positions, and the cutters would have taken up the positions of the beacons, simply for the purpose of verification of the extremes, by simultaneous angles. Six triangles then would remain to be sounded: one distinctly for each boat (the seventh that of the principal, not confined, but to make up deficiences) until it had been *satisfactorily* completed: the objects once in position might remain there for weeks, if necessary, the working boats being hoisted up nightly.

In the general plan this will be more apparent, as it will be seen that the ship will take up the position of the N. beacon; in order to make observations on the reef, fix a station at all times visible, determine the rise and fall of tide, and perhaps rate the chronometers. Where a man enters heart and soul into his duties, even the half tide rock is a luxury only to be appreciated by the surveyor; cut off probably for weeks from more than the monotonous views of trees or land he cannot approach nearer than half a mile.

[A method termed "Surveying by Quincunx," differing very slightly from mine, and even alluding to the beacons, was published by Dalrymple in 1806, but until I saw the term alluded to in a letter in 1833, I had not the slightest idea that it had ever been proposed. So little did my ideas in 1830, (when I commenced my work,) involve five vessels, that I only contemplated *three*, and for that season worked along a considerable portion of coast with that number, latterly adding beacons, then invented by myself. My principle comprehended dispatch, which could not be better promoted than by the single series of equilateral triangles, and for the purpose on which I was engaged I should have continued them an end in *single triangles.* The *system* of the Quincunx differs from mine therefore in two essential points. Rocks, or foul ground, may render it advisable to alter the form, extend the bases, (verifying by *temporary* supplementary,

and *simultaneous* angles,) and the principle of motion in a continuous, line could never be adhered to in tortuous channels, coasts, &c. 2ndly, The *form* is not mine. The *principle* I admit is the same, and Mr. Dalrymple's the *prior merit*; at the same time I cannot but feel gratified that I should have hit upon the plan of so able a surveyor, without the knowledge at that period that he had written.

The Quincunx never was adopted by me: by my method with five there never would be a *central* vessel, and as to proceeding in line by keeping two in line, the distance would preclude this.

A reference to my method of forming the first four equilaterals will show how my principle varies, it being the extension of bases on *one great equilateral*, and had it been necessary to have elongated, two great similar equilaterals would have been projected, N.E. and S.E. This will be more clearly shown in future examples.]

It has thus far been shown how a frigate may practise her volunteers. We will now merely change the names of the objects, and assume the surveying vessel, and proceed to show how the survey proceeds from such "small beginnings." A stricter test must now be applied.

The establishment available for surveying purposes has already been treated on in the frigate survey, and to the largest ship of the line the same may safely apply. Whatever may be the size of the vessel, the principles in which all are involved, are the direction, the orders, and the clear copy on the formula.

Let it be supposed, then, that a corvette, or brig, having a pinnace, cutter, jolly, and gig, is required to conduct such a survey. [It is advisable at all times to retain a boat at the ship, or immediately within hail, in the event of a man falling overboard.] Buoys or beacons can readily be formed; and it will only be necessary to construct as many triangles as can conveniently be sounded. The orders for such will be met under the formulæ and diagrams given. Two equilaterals only could be conveniently formed on the base of ship to pinnace, (which latter would be stationary,) the beacons occupying the other two, forming a diamond-shaped figure, preserving, if possible, the base east and west, or on the meridian. The gig and cutter would thus be left to sound out their triangles, the jolly being employed working out those in the immediate neighbourhood of the ship, which could easily be assisted by her own buoys, or others laid down within a mile.

To a vessel having two boats, the base should be formed on one and ship, and observers in each take simultaneous angles to the

sounding boat by signal. If beacons are not readily procured, this must be practised in the corvette's survey, each spare boat keeping to her own triangle, and a different answering pendant established for each. In all cases, the angles taken should be numbered, and time noted. This helps the principal in clearing up doubts by the "deck-book."

It may frequently occur that one boat only may be available. Under such circumstances a buoy must be placed at the distance of at least a mile, (*in order that magnetic observations may be avoided,*) and each time the angle must be taken to the buoy, the observer at the same moment taking the height of spars to determine his distance. The astronomical bearing of the buoy being of course determined during the survey, all angles taken to the working boat would be true bearings.

A surveying code should always be combined with the boat signals, which may very readily be done, and causes less confusion; and the number of flags should be as limited as possible.

An officer is frequently despatched to examine for anchorage in creeks, bays, &c., little known, or just discovered. Sounding may satisfy him that depth and holding ground are good, but he should always bear in mind that labour should never be in *vain ;* nor should he sacrifice the object of his mission to too minute detail. If he can land, well, let him select two points from which he may be able to fix four or five objects to be used in laying down his soundings; and if he can *pace* his base, good, but time is too precious for measurement. If he be unable to land, lay down buoys, barécas, &c., and if he do not succeed in laying down land objects, endeavour to form small triangles on his buoys; so that after his report, he may readily be enabled to afford his chief a satisfactory proof of his examination, and, not the least important consideration, prove his value for such, or other important duties.

Ability in those under our command is always a source of gratification; and there is a kindly feeling always excited between the parties when opportunities are afforded for its exercise. Envy, it is true, too often succeeds; and there is no greater source of discontent than when those superior in rank fancy themselves slighted by preference shown to ability. Too prone to overrate their own, by the false medium of seniority, they rush on precipitately to evince their laudable ardour to become efficient, and thus render all their labour

of no avail. Who suffers, where the shaft lights eventually, is too evident.

The volunteer may at all times justly claim a preference, but there is a secret telegraph by eye which tells more than the tongue can express. In fact, an officer of ability may be clearly read, *he needs no order*, a nod is quite sufficient answer, and the manœuvre is frequently complete before others have thought of it.

As the survey will now be carried on with the establishment of a surveying vessel, (as in his Majesty's ship Etna,) we will compare them with that of the frigate, and substitute them on Plate VI.

Thus,	Ship	376 tons.	
	Tender	104 tons = △ mark.	
Hoisted in	1st barge....	5 tons 9 ft. bm.	decked and coppered.
	2nd barge ...	5 tons	
Stowed in the barges.	1st cutter ...	25 feet 7.6 beam	Carvel. Line of battle
On quarters generally.	2nd cutter ..	25 „ 7.6 „	ships raised.
	1 whale boat.	32 „ 6 „	
	1st gig......	27 „ 5 „	
	2nd gig	20 „ 4 „	
Tenders............	1st gig......	25 „	
	2nd gig	25 „	
Tub boat	4		
	4 Beacons ..	40 galls. (lately 60.)	

Objects 15

Comp. with Frigate Survey.

Frigate.
Launch.
Barge.
Pinnace.
1st Cutter, or Red Beacon.
2nd Cutter, or White ditto.
Gig, or Blue ditto.
Jolly, or Yellow Blue ditto.
2 Beacons.

10 objects.

The bases having been determined, we must now transfer the attention to Plate VI., where the stations are transferred, omitting the beacons of the frigate plan, and substituting the objects as above.

As the orders will convey a clearer idea of what is to be performed, we cannot do better than introduce them here.

No. 1.

♄ 5 $V/_{32}$. First Cutter. Lieutenant K.

You will proceed with the red beacon S. 45° E. by compass, in company with the tender, (both using pat. log.,) and place the beacon on that bearing five miles (not less) from the ship. Moor the beacon securely with the tide, and assist in laying out warps to enable the tender to approach within a few feet of it. The ship will (when the tender denotes she is ready) fire three guns. Note the beats minutely. The tender will then fire, (possibly the barges.) Take angles to all objects in position. During the time the tender is employed in mooring in position, employ yourself in sounding out the space as noted by the elongated dots in the subjoined diagram. (The Y. B. beacon will be placed by first barge.)—*Vide* Plate IV. diagram for boat's orders.

On the tender mooring, you will return to the beacon, and take a new round of angles to all objects. After this, endeavour to work out the small dotted lines of soundings, (obtaining angles at Y. B. beacon.) The lines will bring you on a wind, on your southern legs, and steering about E.N.E. on the northern; tide in favour by the time you leave yellow blue beacon; return by sunset.

E. B.

No. 2.

♄ 5 $V/_{32}$. Second Cutter, No. 2. Triangle, No. 1. Lieut. L.
Station No. 1.

Proceed with white beacon N. 75° E. by compass, five miles, (or mark on foremast to the horizon.) Wait until the red beacon is moored; then moor the white beacon at an angle of 60°, or nearly, observing the bearing of ship and beacon respectively, as S. 75° W., and S. 15° W. (as nearly as you can estimate.) Wait until the guns are fired for base, observing, (as is noted in signal-book,) that the *flash will follow the motion of the flag to the truck after dipping.* Note the beats. The tender will then fire under similar regulation. Note the beats, and immediately take a round of angles to all objects, including the tender in the *first,* (as she will shift within five minutes after firing.) You will then endeavour to work out the lines of soundings, as in subjoined diagram, (or on reverse to save paper,)

returning to ship by sunset. The operations may easily be performed under canvas.—*Vide* Diagram No. 2, Plate IV.

♄ 5 V/32. Second Barge. Mr. W. M., Mate. Stat. No. 1.

You will proceed, assisted by gig, and moor blue beacon N. 15° E. (by compass) from the ship, at an angle of 60° between ship and white beacon. You will then stand on to your own position, N. 75° E. by compass from the beacon, and ship bearing S. 45° W. Endeavour to take up position with white beacon and tender in line, angle 60° between beacons, and 30° between ship and either beacon. Moor taut and show usual signal. (Gaff topsail,* latteen, which shows 44 feet above the sea level.) Look out for ship firing under customary signals. Be particular in placing marks on your cables when taut, that in the event of veering or slipping, you may easily resume your station.

No. 3.

♄ 5 V/32. △s. First Gig. Lieut. A. No. 1 Station.

You will proceed in the tender accompanied by the first cutter S. 45° E. five miles, measured by patent log. The cutter will then moor the beacon. Anchor clear of it, but so as to allow of your veering alongside of it, steadied by warps, which the cutter will assist in laying out. When ready, make the customary signal. The ship will then fire three guns at five minute intervals, dipping after each time, and hoisting when about to fire. You will fire three guns under similar regulations, commencing ten minutes after the ship has *finished*. (As should I deem it advisable, more guns may be fired, which will be apparent to all by the flag remaining *only dipped.*) You will then proceed S. 15° W. by compass, or keeping the red and white beacons in line, until the angle between the ship and

* Mast	28	above deck.
Topmast	20	
Yard	6	
	54	
Deduct	10	for mast-head, &c.
	44	

It is not less than 50.

beacons = 30°; and that between red and yellow blue beacons, 60°. Moor and take round of angles to be sent by nearest returning boat.

For gig.—You will then endeavour to work out the soundings as in annexed diagram, No. 3 Plate IV. The wind being W. by N. your traverses may easily be performed under canvas. The tide will be favourable, and you will be enabled to return with flowing sheet at sunset to your vessel, bringing me your angle-book in the morning when you come for the orders.

No. 4.

♄ 5 V/32. First Barge. Mr. W. M., Mate. No. 1 Station.

Proceed, assisted by △s second gig, and place Y. B. beacon S. 15° W. from ship at an angle of 60° between red beacon and ship. You will then obtain soundings on a line 15° to the southward of red beacon, until you bring red beacon and ship in line; then haul up N.E. until you bring red and yellow blue in one; stand on in that direction until the angle between red and white beacons = 60°,* ship with either = 30°. The second gig will rejoin and assist in mooring. Look out for the base signals. The △ will fire after the ship has hauled down. Be particular in placing marks on your chain-cables when taut, that in the event of veering or slipping, you may easily resume your station.

No. 5.

♄ 5 V/32. Gig. No. 5 Triangle. J. C., Mate. No. 1 Station.

Proceed with the second barge, and place the blue beacon, considering the orders of 2 B. as applying to yourself until you have moored her in position, and the ship and tender have fired their guns. (Probably the flash of the guns of the latter will not be seen excepting at the mast-head.) On quitting the second barge endeavour to complete the soundings as dotted in the diagram beneath, (or on reverse, if convenient,) returning by sunset.—*Vide* No. 5 diagram Plate IV.

* From your mast-head, *yellow blue, and red,—blue, and white* should each be in line. Flags twenty feet above level; mast-head, twenty-eight; distance, ten miles.

No. 6.

♄ 5 V/32. Second Gig. 3 and 5 Triangles. Mr. C.
No. 1 Station.

Proceed to blue beacon, and measure base by tender and ship's guns; then endeavour to complete the line of soundings in annexed diagram; returning to the ship at sunset.—*Vide* No. 6, Plate IV.

No. 7.

♄ 5 V/32. △s Second Gig traverses 1. 2. 4 triangles. Mr. M., mate.
No. 1 Station.

Proceed with first barge, and place Y. B. beacon, considering the orders of 1 B. as applying to yourself, until you have moored her in position, and the ship and tender have fired their guns. On quitting the Y. B. beacon, proceed by a route 15° N. of red, (the barge going S.,) and rejoin her at position (or before anchoring.) You will then endeavour to complete the lines of soundings as dotted in the diagram, returning by sunset. As the tide at that period will run to the N.W., make your long legs southerly.—*Vide* Diagram No. 7, Plate IV.

No. 8.

Whaler. Mr. C. (confidential.)

Proceed to Y. B. beacon, and obtain results of reports of ship and tender's guns; return by a westerly route, or as high as the wind and tide will permit you to lay, until the white beacon and ship are in line: thence to ship.

Propose to proceed myself (in whaler on return) to examine No. 3 triangle, get angles at white beacon, and work over ground; viz. stood to eastward under easy sail, brought white beacon and 2 B. in line, red and △ do., (well placed,) hauled to northward, took angles at white beacon, on to N.W.; tacked to southward, tacked to northward, tacked, to ship—(6·20.)

Such, then, would be the series of orders which should be given to each individual. If the service be not completed the first day, the

same, perhaps, with some slight addition or explanation, will be acted on for the next. It must be evident to all, that as the principal has to put all the data on paper, he can have no *spare* moments for explanations.

The first difficulty, then, that of placing the stations and determining the bases, is overcome, and we have also a mass of soundings, but not sufficient to satisfy the principal, where shoal water has been met. He must distinctly outline all banks of three fathoms. He will not be able to shift his objects yet, and until the data be laid down fairly, cannot decide in what direction his next move may be. He knows sufficiently, however, from his rough diagram, what is yet required, and therefore his orders for the following day will be in assigning each boat her triangle, to cause her to work from, or towards an apex, as nearly opposite to that of the day before as possible. Thus let us resume the first cutter's.—No. 1, Plate IV., and refer to the *last repeated* on same Plate.

The apex worked to on ♄ 5th, is the ship. On reference to the diagram, the spaces are very open. Now the amount of *labour* is equally part of the surveyor's calculation, and with the wind at W. (true,) he is to consider how the ground is to be cut up, *wind and tide assisting*. The thick dots shall denote the second day's work. (☾ 7th.) Thus, on a wind, with his oars he may make his northern boards until the tide changes, and under easy sail southerly. He will then have sounded from the apex red, to ship. If a third be *required*, it must be done on the oars—from Y. B. Apply tracing paper to each diagram, and take off the lines on which each boat has been directed to work, and some estimate may be formed of what they have been about. The principal is now enabled to form his ideas of what may have been lost on the preceding day, and having fully as much as will occupy him, he so plans his orders that they may meet his contemplated movements. Thus he learns that the reef was seen out of water between the barges, and his attention is directed to the boats occupied in the three nearest triangles to sound up to it; and his own boat forwarded to examine the possibility of placing his ship in a convenient position near it.

Having thus far explained the construction of the primary bases, we will proceed to investigate the triangles and compute the mean base, and determine the positions in latitude and longitude.

This, although not forming part of the system of *rapid* boat or ship survey, affords infinite satisfaction to the young surveyor, and leads

him to investigate more minutely the nature and truth of his operations, which, if they bear the test, materially tend to give him confidence. In the service on which we are now treating, (the surveying department,) and which we are now carrying on towards the land, this is called for, as we have not yet secured any *decided* position in latitude or longitude; and by thus keeping up the system, rocks, or other dangers, are instantly assigned their position by merely stating what error was detected when the land became connected, as will shortly be apparent. We have already classed the triangles in the "frigate survey," and having now substituted other names, will proceed to investigate the true base from the series of admeasurements. It is to be presumed that the common principles of plane trigonometry are understood, and that the work is to be computed by it. These are generally comprehended in oblique angled trigonometry, viz.

For a side—As the angle opposite the given, : is to the given side : : so is the angle opposite the side required : to the side required.

For an angle—As the given side of a triangle is to the sine of its opposite *given* angle, so is any other given side to the log. sine of the angle opposite that side.

It frequently occurs that we have the sides and included angle, and that we wish the third side (not perhaps measured) to complete the side of one greater triangle. We then have to compute the angles, which is done thus:

Subtract the angle, subtending the sides from 180°, and half the remainder: this is half the sum of the angles required. Then say, As the sum of the sides : is to their difference : : so is the tangent of this half sum of the angles : to the tangent of half their difference. It is evident, then, that by adding this to the half sum, we obtain the angle opposite to the greater side, and, by subtracting it, the lesser. Now it is customary in these proportions to take the arithmetical complement of the first term, to save trouble and space. This is well known to every one conversant with navigation. However, there may be others who are not, and as the object is to prevent the necessity of reference to other books, I shall simply state it. The arithmetical complement is the log. subtracted from 10.000000, and is done with more facility by subtracting each figure, commencing on the *left*, from 9, excepting the last *number*, which is from 10. As the log. of 305. = 2·484300 co. ar. = 7·515700, the 3 is taken from 10.

In taking out the logarithms of *angles*, *time* and *accuracy* may be met thus:—

The ar. comp. of a *log. sine* is its	*cosecant*;	thus,	20°15′=9.539223=0.460777
Cosine	. *Secant*	.	20.15=9.972291=0.027709
Tangent .	. *Cotang*	.	20.15=9.566932=0.433068

and *vice versâ*. Thus, in writing down the rough work, put after the term, before the space for the logarithm, its abbreviation; as, log. cosi. =(Sec.)

These points, trivial as they appear to those accustomed to such calculations, are little known amongst the youth of our profession; but a few reflections of this nature will induce them to investigate *why they are so*, instead of plodding on with formulæ which they have learnt by rote.

Multiplication is effected by adding together the logarithms of multiplier and multiplicand.

Division, by subtracting the logarithm of the divisor from that of the dividend.

Proportion.—To the arithmetical comp. of the log. of the first term add the logs. of the second and third.

Involution.—Multiply the log. of the given number by the *index* of the power.

Evolution.—Divide the log. of the given number by the index of the power.

The common methods of multiplication by decimals are more liable to error than the very simple form by logarithms, which will be made use of in preference.

First, the mean measurement between ship and red beacon = 66·6 beats, and 5 beats equal 2 seconds, then double 1142 = 5 beats, or 2284 ÷ 5 = 456·8 feet.

Then 66,6 log. =	1·823474		At white beacon = 68,0	1·832509
1 beat=456,8 . . .	2·659726		456,8 . .	2·659726
30422,8 =	4 483200	ship to red bea.	White and ship 31062,3 .	4·492235
Ship and blue 67,33	1·828209		Ship to yellow blue 66,3	1·821513
456,8 .	2·659726		456,8 . .	2·659726
30756,4	4·487935		30285,4	4·481239

* It is surprising that landsmen have not yet availed themselves more generally of these tables.

White to red 68,33	1·834611
456,8	2·659726
31213,2	4·494337

Yellow B. to red 66	1·819544
456,8	2·659726
30148,8	4·479270

Ship to 1 B. 118,4	2·073352
456,8	2·659726
54085,2	4·733078

Red to 1st barge 68,7	1·836957
456,8	2·659726
31382,2	4·496683

Ship to 2nd barge 117,5	2·070038
456,8	2·659726
53674,0	4·729764

Having thus obtained these measurements, let us, assuming each as being the sole determination, refer them to *one distinct base;* and, as the original has been worked on that between ship and red, (because the guns were at its extremities) we will prefer it.

Ship to red, by sound = 30422,8 Or 4·483200

On beacons W. and red=31213,2=4·494337

Ship and white 31062,3 or 4·492235

Ship 61° 5′	As 60° 30′ cosec.	0·060303
Red 60 30	: base, ship W.	4·492235
W. 58 25	: : 58 25	9 930378
	Ship to red	4·482916

Same △	As 61° 5′ cosec.	0·057832
	: base	4·494337
	: : 58 25	9·930378
	: ship to red	4·482546

On base, ship blue 30756,4 = 4·487935

Ship 58° 33′	As 60° 10′ cosec.	0·061742
W. 60 10	: base	4·487935
B. 61 17	: : 61 17	9·943003
	Ship to white	4·492680

On base ship to Y. blue 30285,4 = 4·481239

Ship 59° 47′	As 59° 43′ cosec.	0·063716
Y B 60 30	: base	4·481239
Red 59 43	: : 60 30	9·939697
	Ship to red	4·484652

On ship W. (on base, ship blue) 4·429680

Ship 61° 5′	As 61° 05′ cosec.	0·060303
Red 60 30	: base	4·492680
White 58 25	: : 58 25	9·930378
	: ship to red	4·483361

On base, Y B to red 30148,8 4·479270

Ship 59° 47′	As 59° 47′ cosec.	0·063422
Y B 60 30	: base	4·479270
Red 59 43	: : 60 30	9·939697
	: ship to red	4·482389

On base 1 B. Red 31382,2	4·496683	On base beacons . . .	4·495224
W. 60° 10′ As 60° 10′ .	0·061742	As 61° 5′ . . .	0·057831
Red 60 0 : base . . .	4·496683	△ 1 . . : base . . .	4·495224
1 B. 59 50 : : 59 50 . .	9·936799	: : 58 25 . . .	9·930378
: beacons .	4·495224	: ship to red . .	4·483433

Now the simplest method is to take the mean of the logarithms—

On 1st base : ship and white . . .	4·482916 =	30403.0
2d . . beacons, W. and red . .	4·482546	30377.0
3d . . . ship and blue (5) . .	4·483361	30434.0
4th . . ship and yellow blue . .	4·484652	30524.8
5th . . Y B to red . . .	4·482389	30366.0
6th . . 1 B. to red (8) . .	4·483433	30439.2
6)	19297	
Mean (1st by sound excepted) . .	4·483216	
1st taken for work . . .	4·483200	30422.8
		30423.83
Adding this, and dividing by 7 . .	4·483214 ; or =30423,9 mean base	

On this base, then, we proceed to compute the triangles, to obtain the stations, 2nd barge, 1st barge, and tender = △.

COMPUTATION OF TRIANGLES.

1st Triangle.

Ship 61° 5′	58° 25′ cosec.	0.069622	Course S. 60° 47′ 51″ E. 5′.008 m.
Red 60 30	Mean base	4.483214	D. lat. 2′ 26″,4 = 11° 22′ 43″,6 N.
White 58 25	: : 61.5 sine	9.942169	D. long. 4′ 27″,0 = 16 56 18,0 W.
			Position of Red Beacon from ship.
180 0	Beacons, 31261,2	4.495005	
Base ship to red			
by sd. 4.483199	Again, as 58° 25′ cosec.	0.069622	Course N. 58° 7′ 9″ E. 5′. 116 m.
Or, feet 30422,88	Base	4.483214	D. lat. 2′ 42″,0 = 11° 27′ 52″,0 N.
	: : 60. 30 sine	9. 939697	D. long. 4′ 25″,8 = 16 56 19,2 W.
Mean 4.483214			Posn. of White Beacon from ship.
	Ship to Wh. 31083,7	4. 492533	

2nd Triangle.

Ship 58° 33′	61° 17′ cosec.........	0.056997	Course N. 0° 26′ 9″ W. 5′,060 m.
White 60 10	: base	4.492533	D. lat. 5′ 36″,0 = 11° 30′,13″,6
Blue 61 17	: : 60.10 sine	9.938258	D. long. 0′ 2″,3 = 17 0′47,3
———		———	Posn. of Blue Beacon from ship.
180 0	: Ship to Blue, 30746	4.487788	

Base last found .. 4.492533

61° 17′ cosec.	0.056997	Course N. 61° 42′ 51″ W. 4′,977 m.
: base	4.492533	D. lat. 2′ 21″,0 = 11° 30′ 13″
: : 58.33 sine	9.930998	D. long. 4′ 28″,2=17 0 47,2
	———	Position of Blue from White.
Blue to white, 30236,3	4.480528	

3rd Triangle.

Ship 59° 47′	60° 30′ cosec.........	0.060303	Course S. 1° 0′ 51″ E. 4′,969 m.
Red 59 43	Mean base	4.483214	D. lat. 4′ 57″,6 = 11° 20′ 12″,4
Y. B. 60 30	: : 59.43 sine........	9.936284	D. long. 0′ 5″,4 = 17 0 9,6
———		———	Yellow Blue Beacon from ship.
180 0	: ship to Y. B. 30185,7	4.479801	

Mean base .. 4.483214

As 60° 30′ cosec.	0.060303	Course S. 59° 29′ 9″ W. 4′,971 m.
: base	4.483214	D. lat. 2′ 31″,2 = 11° 20′ 12″,4
: : 59.47 sine	9.936578	D. long. 4′ 21″ 6= 17 0 39,6
	———	Position of Y. B. from red.
Y. B. to red, 30206,2	4.480095	

4th Triangle.

1st B. 59° 50′	59° 50′ cosec.........	0.063201	Course N. 59° 42′ 9″ E. 5′,163 m.
White 60 10	Base	4.495005	D. lat. 2′ 36″,2 = 11° 25′ 19″,8
Red 60 00	60.10 sine	9.938258	D. long. 4′ 32″,8 = 16 51 45,2
———		———	Position of 1st barge from Red.
180 0	R. and 1 B. 31366,4	4.496464	

Base, beacons .. 4.494005

59° 50′ cosec.........	0.063201	Course S. 60° 27′ 51″ E. 5′,154 m.
Base	4.495005	D. lat. 2′ 32″,4 = 11° 25′ 19″,6
: : 60 sine	9.937531	D. long. 4′ 34″,2=16 51 45,0
	———	Position of 1st barge from White.
W. and 1 B. 31314	4.495737	

5th Triangle.

Blue 60° 15′	White 58° 30′ cosec...	0.069234	Course N. 58° 1′ 51″E. 5′,117 m.
White 61 15	: base	4.480528	D. lat. 2′ 42″,6 = 11° 32′ 56″,2
2 B. 58 30	: : 61.15 sine........	9.942864	D. long. 4′ 25″,8=16 56 21,5
———		———	Position of 2nd barge from Blue.
180 0	Blue and 2 B. 31090,4	4.492626	

Base, blue white .. 4.480528

As, 58° 30′ cosec......	0.069234	Course N. 0° 27′ 51″ W. 5′,068 m.
: base	4.480528	D. lat. 5′ 4″,2 = 11° 32′ 56″,6
: : 60.15 sine	9.938619	D. long. 0′ 2″,5 = 16 56 21,7
	———	Position of 2nd barge from White.
2 B. white, 30738 ..	4.488381	

6th Triangle.

Y. B.	60° 10′	60° 13′ cosec.........	0.061525	Course S. 0° 7′ 51″ E. 4′,970 m.
Red	59 37	Base	4.480095	D. lat. 4′ 57″,6 = 11° 17′ 46″,0
△	60 13	: : 60.10 sine	9.938258	D. long. 0′ 0″,6 = 16 56 17,4
	180 0	: △ R. to 30191	4.479878	

Base Y. B. red .. 4.480095

60° 13′ cosec........	0.061525	Course S. 60° 21′ 51″ E. 4′,941 m.
: base..............	4.480095	D. lat. 2′ 26″,4 = 11° 17′ 46″,0
: : 59.37 sine	9.935840	D. long. 4′ 22″,8 = 16 56 16,9
	———	= △ = Tender from Yellow Blue.
: Y. B. to △ 30023,4	4.477460	

PROOF OF THE OBTUSE ANGLES.

1st N.

2 B. & Blue	31090,4	121° 32′	As 61836,4 co. ar.	5.208759
Ship & Blue	30746,0	2) 58 28	: 344,4	2.537063
		29 14 ½ ∠s.	: : tang. 29.14	9.747913
Sum	61836,4	10 43	Tang. 10′ 43″	7.493735
Diff.	344,4	29 24 43 = ∠ opp. gr. side.		
		29 3 17 less.		

Ship . 29° 24′ 43″	as 29.3.17 cosec.		0.313681
Blue . 121 32 0	: Base, ship & blue		4.487788
2 B. . 29 3 17	: : 121° 32′ sine		9.930611
	Ship to 2 B .	53961	4.732080

2nd.

Ship white	. 31083,7	121° 25′ 00″	As 61871,7 co. ar.	5·208506
W. 2. B.	. 30788,0	2) 258 35 00	: 295,7	2·470851
		29 17 30	: : tang. 29° 17′½	9·748949
Sum	61871,7	9 13	Tang. 9′ 13″ =	7·428306
Diff.	295,7	29 26 43 opp. gr. side.		
		29 8 17 less.		

Ship . 29° 8′ 17	As 29° 26′ 43″ cosec.	0.308395
W. . 121 25 0	: Base, ship white .	4·492533
2 B. 29 26 43	: : 121 25 sine .	9·931152
	Ship to 2 B. 53961 =	4·732080

3rd.

1 B. & W.	. 31314,0	118° 35′ 0″	As 62397,7 co. ar. .	. 5.204836
Ship & W.	. 31083,7	2) 61 25 0	: 230,3 .	. 2.362294
	———	30 42 30	: : Tang. 30° 42′½ .	. 9.773752
	62397,7	7 32	Tang. 7′ 32″ =	7.348882
	230,3	30 50 02 opp. gr. side.		
		30 34 58 less.		

Ship . 30° 50′ 2″	As 30° 34′ 58″ cosec.	0.293467
1 Barge 30 34 58	: Base, ship white .	4.492533
White 118 35 0	: : Sine 118·35 .	9.943555
	: Ship to 1 B. 53648,0=	4.729555

4th.

1 B. & Red .	31366,4	120° 30′	As 61789,2 cosec. .	. 5.209089
R. & S. .	30422,8	2) 59 30	: 943,6 .	. 2.974788
	———	29 45	: : Tang. 29° 45′ .	. 9.757052
	61789,2	30	Tang. 30′ 0″ =	7.940929
	943,6	30 15 opp. gr. side.		
		29 15 less.		

Ship . 30° 15′	As 29° 15′ cosec. .	0·311028
1 B. . 29 15	: Base, ship red (mean.)	4·483214
Red . 120 30	: : 120° 30′ . .	9·935320
	: Ship to 1 B. 53649=	4·729562

5th.

Ship & R. .	30422,8	119° 20′ 0″	As 60613,8 co. ar.	. 5.217435
R. & △ .	30191,0	2) 60 40 0	: 231,8 .	. 2.365113
	———	30 20 0	: : Tang. 30° 20′	. 9.767255
	60613,8	7 42	: Tang. 7′ 42″ =	7.349803
	231,8	30 27 42 opp. gr. side.		
		30 12 18 less.		

Ship .	30° 12′ 18″	As 30° 27′ 42″ cosec.	0·295025
Red . .	119 20	: Base, ship red . .	4·483214
△ .	30 27 42	: : 119° 20′ sin. . .	9·940409
		Ship to △ 52317,9=	4·718648

6th.

Ship & Y.B. 30185,7	120° 40′ 0″		As 60209,1 co. ar. .	5·220339
Y. B. & △ 30023,4	2) 59 20 0		: 162,3 .	2·210318
	29 40 0		: : Tang. 29° 40′ .	9·755585
60209,1	5 17		: Tang. 5′ 17″ =	7·186242
162,3	29 45 17	opp. gr. side.		
	29 34 43	less.		

Ship .	20° 34′ 42″	As 29° 45′ 18″ cosec.	4·304266
Y. Blue	120 40	: Base, ship Y. B. .	4·479801
△	28 45 18	: : 120·40 sine .	9.934574
		Ship to △ 52317=	4·718641

Thus then we obtain Ship to 2nd barge 53961 feet ang. from red 90° 13′ 17″ northerly.
1st . . 53648,5 . . 30 15 0 „
△ . . 52317,45 . . . 30 12 18 southerly.

Red true bearing=S. 60° 47′ 51″ E.+90° 13′ 17″=151° 1′ 8″ or N. 28° 58′ 52″ E
Which will give 60 47 51 +30 15 0 = 91 2 51 or N. 88 57 9 E.
60 47 51 −30 12 18 = 30 35 33 or S. 30 35 33 E.

The next object will be to reduce these to latitude and longitude. First we have the 2 B. bearing N. 28° 58′ 52″ E. 53691 feet. The next point therefore is to reduce this to nautical miles, which is simply done by subtracting the log. of 6075,6 (number of feet to a nautic mile) from that of 53961,0.

Therefore, 53961,0	4.732080	1st B. 53648,5	4.729558	△ 52317,0	4.718644
6075,6	3.783589		3.783589		3.783589
8,881 miles=	0.948491	8,83 miles=	0.945969	8,611 miles=	0.935055

For position on 2 B.

Then, as rad.	0.000000	Lat. of position ship ..	11° 25′ 10″ N.
: dist. 8,88	0.948491	Diff.	7 46,2
: : cosi. bearing, 28.58.52 ..	9.941900		
		Lat. of 2 B.	11 32 56,2
: diff. lat. 7′,77=7′,46″,2 ..	0.890391		
		Mid. lat.	11 29 33

As sec. mid. lat.	0.008795	Long. of ship's position	17° 0′ 45″ W.
: dist.	0.948491	Diff. long.	4 23,4 E.
: : sine bearing 28.58.52 ..	9.685313		
		2 B. position	16 56 21,6
: diff. long. 4′,39=4′,23″,4..	0.642599		

Then, Lat. of 2 B. is fixed....	11 32 56,2 N.
Long.	16 56 21,6

For 1 B. position.

1 B. bears N. 88° 57′ 9″ E. 53648,5 feet, or as reduced before 8′,83 miles.

As rad.	0.000000	Lat. ship's position	11° 25′ 10″ N.
: dist. 8.83	0.945969		9,6
: : cosi. bearing...........	8.262007		
		Position of 1 B.	11 25 19,6
0′,161=9″,66	9.207976		
		Mid. lat.	11 25 14

As sec. mid. lat.	0.008685	Long. position	17° 0′ 45″
: dist.	0.945969	Diff.	9 0
: : sine bearing...........	9.999927		
		Long. 1st barge	16 51 45
diff. long. 9′,007..........	0.954581	Lat.	11 25 19,6

The bearing of the △= tender is, S. 30° 35′ 33″ E. 52317, or=8′,611 miles.

As rad.	0.000000	Lat. of ship	11° 25′ 10″ N.
Dist. 8.611	0.935055	Diff.	7 24,6
: : cosi. bearing, 30° 35′ 33″	9.934919		
		Position of △	11 17 45,4
7′41, or 7′,24″,6	0.869974		
		Mid. lat.	11 21 27
As sec. mid. lat. 11·21·27....	0.008589	Long. ship............	17 0 45 W.
: dist....................	0.935055	Diff.	4 28,2
: : sine bearing	9.706657		
		Long. of △	16 56 16,8
4′,47 or 4′,28″,2	0.650301	Lat. of △	11 17 45,4

Having determined our principal positions, directly, and circuitously, we will now tabulate them for convenient reference.

Position.	Whence determined.	Mean Lat.	Whence determined.	Mean Long.
Ship	By astronomical Obs.	11° 25′ 10″N.	Astronomical Obs.	17° 0′ 45″ W.
2 Barge .	From Blue 11° 32′ 56″.3 White .. 56.6 Ship (direct) 56.2	11 32 56,37	Blue....16° 56′ 21″.5 White .. 21.7 Ship 21.6	16 56 21,6
1 Barge .	Red .... 11.25.19.8 White .. 19.6 Ship (direct) 19.6	12 25 19,7	Red....16.51.45.2 White .. 45.0 Ship.... 45.0	16 51 45,07
△Tender	Red .... 11.17.46.0 Y. B.... 46.0 Ship (direct) 45.4	11 17 45,8	Red ....16.56.17.4 Y. B. .. 16.9 Ship 16.8	16 56 17,03

The angles for extending the bases beyond the reef will now be made use of, introducing the ship instead of a beacon at that position; it having been determined that there is sufficient water and no dangers N.W. of her position; (the strong winds blowing from S.E.) In moving to this position then, such deep water soundings as can be obtained outside of the triangles are worked over by the ship, as proceeding by the N.W. tack outside of blue, round 2 B., as noted in track. Having moored in position, a general round of angles is obtained. The depth of water in the neighbourhood of 1 B. and beacon renders it advisable to shift △ tender, so as to preserve her distance on the same bearing as before from the ship; but this must follow the shift of Y. B., which will take up a position south of 1 B. The tender will then advance on the same bearing to complete the triangle east of 1 B. The red, on its own line of bearing, past 1 B. to R^2. The white, after the necessary angles to the reef, to W^2, on its continuous line past the ship. The principal having placed marks (staves) on the extremities of the reef, obtains angles from ship, barges, and white beacon. The moving of the beacons will be performed by the cutters; 2 C. to blue, and white; 1 C. to yellow-blue, and red.

The following abbreviations, or symbols, will be adopted: S. = ship, $S.^2$ = ship at 2nd position, or the numbers over each denoting the number of the station; △ = tender; 1 B. = 1st barge; 2 B. = 2nd barge; W. = white beacon; R. = red beacon; B. = blue beacon; Y. B. = yellow blue beacon.

The angles will then be repeated for this general shift of positions, taking them in their order. Thus the ship commences, and we shall suppose her track only to be inserted to keep up the practice.

FORMULA FOR DECK BOOK.

Date.	Times.	Altitude.	Ship's head steering comp.	Azimuth.	Pat. Log.	Soundings, Angles, Views, &c.
6th.	h. m. s. 7 20 0	.. ..	N. W.	N. 42° W.	Not used	Stood to N.W 9 . . 10 . 11 . 10½ 12 . 13 ∠s { R. and W.........41° 35′ / W. and 2 B. ......44 36 }
						14 . 15 . 17 B. and 2 B. in line ∠ W. to objects ....45° 35′
						17 . 19 . 20 . . 21 B. and W. in line. Objects to 2 B..................41° 30′
	8 0	.. ..	.. ..	.. ..		20 . 19 . 18, 17 . 16, 15 { B. W............56° 50 / W. to 2 B........58 52 }
						14 . 12½, 11, 10 . . 9 barges in line. B. to objects ....76° 30′
						9 . 8½ (2 B. and W. in one) 7½ 8 . 7 . . ., 2 B. and B. in one, ∠ to 1 B. 74 5
						7 . . . 6 . . . . . . 5, 4½ 5 . 5 anchored.
	8 40 0	.. ..	.. ..	.. ..		Anchored in position, moored.
						∠s 2 B. and white beacon.. .... 59° 32′ 30″ } 60° 13′
						1 barge.................................... 119 45 30 }
						Observed △ shift and moor, 1 B. and △² 31 3 35
						Red to R² R²................ 60 15 } 59° 32′
						W. to W.² W²................ 119 47 }
						B. to B² W.² and B.² .... 60 12 } 60° 15′ 30″
						2 B................ 120 27 }
						Placed marks on reef.
						∠s 2 B., and Red pendant* .... 24° 25′ = (North object.)
						White............ 88 35 = South.
						Blue .... 54 37 = West.
						W. Blue.......... 42 30 = East.
						Appearance of land from fore-top.
						

	A. T. S. 8 7 22	☉ 33° 28′ 0″	⊙ △ right. 79° 33′ 15″ true	S. 13° E. S. 31° 54′ 16″ E.		∠s △ &c. S. object (monkey tree) (.)............ 41° 50′ Pyramid ....(:)............ 43 44 Arrow clump .... (··)............ 44 57 Cotton clump ....(⁝)............ 48 4 Wedge peak........................ 55 33 Umbrella tree ....(...)............ 59 58 Gull knob ....(|)............ 66 17 Abbey clump ....(–)............ 69 44
7th	.. ..	.. ..	.. ..	.. ..		1 B. shifted, △^{2} 1 B.^{2}. 58° 40′ 13″. 2 B. shifted, 1 B.^{2}, 2 B.^{2}, 60° 52′ 0″ R.^{2} 1 B.^{2} 29° 28′ 50″. 1 B^2 and W^2, 30° 3′ 42″. 5 weighed and stood to northward 5 . . 5½ 6 . . . 7 . . ∠s { W. and umbrella in line R.^{2} and objects 39° 50′ Objects & 2 B.^{2} 50 8 }
	5 0 0					8 . 9 . . 8½ 8 . B.^{2} and W.^{2} in one ; objects to 2 B.^{2}......48° 52′ 8, 7, 8 . . 7½ 7 . { B.^{2} and W.^{2}......48° 56′ W.^{2} and 2 B.^{2}....53 15 } . On 7 6½ 6 . . . 2 B^2 and wedge in line ; ∠ B^2 to objects=84° 46′ On . 6 . 5½, 5 . . . 2 B^2 and W^2 in line ; B^2 and objects = 48° 15′ 5 4½ 5 4½ 4 . . . 2 B.^{2} and B. in line ; objects to wedge = 111° 45′ 4 . . 4½ 5 . 4 . . . . anchored, dark ; objects not visible.
8th	.. ..	.. ..	.. ..	.. ..		Angles by lights. Barges 119° 39′ 35″ Daylight. 2 B.^{2} and W.^{2} 59 17 B.^{3} and 1 B.^{2} 60 10 1 B.^{2} and W.^{3} 60 0 } ∠s to land objects. *Vide* whaler.
9th	.. ..	.. ..	.. ..	.. ..		5° 40′ weighed and stood for river mouth . 4, 5 . . 6 . 5½ 5 . W.^{3} and abbey in line. Objects to elephant.. 59 °0′ On 4½ . . 5, 6 7 . curlew and gull in one Objects to elephant .. 62° 30′ } on towards wedge. 7 . . 8 . 7 . W.^{3} and elephant in one. Umbrella to do. 88° 20′ } On 6 . . 5 . 4 3. On bar { Eagle mount over shag rock, Monkey and eagle .. 113° 10′ Eagle and elephant.. 67 50 } . 2½, 3, . 4½ . 5 . . 6 . 9 . 6 . 5. Spire open of Pt. Crab, and preceding mark on, hauled up for anchorage. 5 . . . . anchored.

* N.B. Where the Principal carries his boat's pendants, they may be used, as he would be himself engaged.

Date.	June 1832. FIRST BARGE.	
6	Observed ship weigh, do. moored.	
	Ship^2 and 2 B.....	29° 54′
	W.	59.37
	R.	119.27
	R. and Y. B.	61.40
	$\triangle$ shifted — $\triangle^2$	120.10
	R. to R^2 — $\triangle^2$ and R^2 ..	59.50
	Ship^2	120.23
	Answered sig., take objects N.W., (not seen from deck,) $\angle$s mast-head.	
	Ship^2, red pendant ...... N.	26° 45′
	W. & W. B. in line E. & S.	18.40
	Blue............. W.	31.13
7	Shifted position to N.E.	
	Moored, $\angle$s, ship^2 and R^2	29° 43′ 34″
	$\triangle^2$......	60.12.50
	W^2, ship^2	29.44.26
	W^2 R^2..	59.28.00
	Observed 2 B. shift to 2 B^2,	
	$\angle$s 2 B^2, W^2 ..	29.31.45
	Ship^2 ..	59.16.10
	Observed Y.B. moor,	
	$\triangle^2$, and Y. B.^{3}........	29.50.45
	Ship shifted, do. moored, showed light per signal.	
	Ship^3 and 2 B^2..........	30° 17′ 30″
8	$\angle$s, Ship^3, and 2 B^2	30.17.30
	W^2......	59.49.16
	W^2 R^2 ..	59.28
	R^3 Y. B.^{3}	62.10.15
	Observed W^2 shift to W^3	
	Y. B.^{3} and R^3	59.57.0
	Do. R^2 to R^3, R^3 & W^3 ..	57.55.30
	Ship^3.	118.35.30
	$\triangle^2$ to $\triangle^3$. Y. B.^{3} and $\triangle^3$	28.58.25
	$\angle$s to land objects.	
	$\triangle^3$ and S. extreme rocks	24° 8′
	S. tangent land........	25.43
	Monkey..............	26.31
	Pyramid	30.45
	Arrow	32.28
	Cotton clump	38.00
	Wedge peak..........	53.5
	Umbrella	61.8
	Tangent of point......	61.52
	Sand (tang. spit in line)	62.34
	Inner point	62.46
	Crane	67.30
	Gull . S. tangent....	71.36
	Gull . Centre	73.36
	Gull . N.	76.5
	Curlew S.	71.6
	Curlew Centre	73.36
	Curlew N.	76.35
	Eaglet Mount........	74.30
	Abbey tangent	78.21
	Abbey clump	79.49
	Crab................	80.18

Date.	June, 1832. FIRST BARGE—*continued.*	
	$\triangle^3$ and N. tangent sand spit ..	82° 12′
	(Mangrove and spire, in line. Do. W.^{3})	89.20
	Water tree	111.0
	East ape	111.45
	West	116.45
	Elephant	126.32
	Tangent	127.30
	Sand	129.35

Date.	June, 1832. SECOND BARGE.	
6	Obsd. ship weigh, 2 do. moored.	
	W. and 1 B.	30° 16′ 50″
	Ship^2	60.37.30
	Observed B. shift to B^2.	
	Ship^3, B^2	60.50.0
	$\angle$s to reef.	
	Objects (S. and N. pennants) in line.	
	Ship^2	22.43
	Blue .... W.	31. 6
	W. blue...... E.	15.43
7	Weighed and stood to N.E.; 10 moored.	
	B^2, ship^2	30° 6′ 20″
	W^2	60.31. 0
	1 B^2, moored; ship^2, 1 B^2 ..	60.21.45
	Ship weighed and stood to eastward; do. moored.	
	1 B^2, ship^3	30° 2′ 55″
	B^2 shifted to B^3, ship^3 and B^3	59.58
	$\angle$s to Land Objects.	
	Ship^3 and gull	7° 35′
	Abbey clump	10.25
	Mangrove	18.21
	Water tree..........	30.30
	Creek	37.33
	to ..	38. 0
	West ape	45.58
	East	46.20
	Elephant	46.56
	Tangent point	48. 0
	Sand	48.45
	Ape Bluff	50. 8

Date.	June, 1832. FIRST CUTTER.	
6	Left ship for Y. B. Ship weighed. Weighed Y. B. and stood to eastward. At 10 moored, Y B^2.	
	1 B. and R.	59° 8′
	$\triangle$	115.34.30

Date.	June, 1832. FIRST CUTTER—*continued.*

$\triangle$ weighed; 2.10 do. moored.
$\triangle^2$ and 1 B. .... 64° 30′
W. 123.38

Proceeded to R. weighed do.
4.40 moored R^2.

Ship and 1 B. 59.12
$\triangle^2$ 122.32.40

Obsd. W. weigh; do. moored.

W^2 ship^2 .... 59.44.30

Returned to ship (6.)

H. K.

8 Left ship for Y. B. 8 weighed Y B.
10.20 moored Y B^3.
1 B^2, R^2...... 58° 37′ 4″
$\triangle^2$......119.59.4

Proceeded to R^2.

$\angle$s $\triangle^2$ and Y B^3 .... 57.27
Y B^3 and 1 B^2........ 59.12.41
1 B^2 and W^2 .... 60.51.00

Weighed R^2 and stood to eastward.
3 moored R^3.

1 B^2 and Y B^3 .... 60° 33′
W^3 moored; W^3 and 1 B^2.. 61.55
$\triangle^3$ moored; Y B^3 and $\triangle^3$.. 57.47.30

Sounded to Y B^3.
$\angle$s at Y B^3; $\triangle^3$, and R^3 .. 61.34

On to gull, per recall from whaler.

H. K.

June, 1832.

SECOND CUTTER.

6 Left ship for blue^2.
Weighed, at 6—Observed ship moor; returned to Y. B.
At 8 moored; 2 B. and ship^2 58° 55′
Sounded and returned to W.

$\angle$s at do. 1 B. & Red Pend. 88. 7
White .. 42.22
Blue ... 64.54
W. blue. 67.40
Ship^2 .. 60.10
2 B.....120. 0

Weighed W.; at 3 moored W^2.

B^2 and ship^2 .... 59.48
Ship^2 and R^2 .... 60.30.51

Returned to ship (6.10)

J. S. L.

Date.	June, 1832. SECOND CUTTER—*continued.*

7 Left ship for W^2.
$\angle$s W^2; 2 B^2, and B^2 .... 59° 29′
B^2, ship^2 .... 59 48
Ship^2, R^2........ 60.30.51
R^2, 1 B^2 .... 59.41
Barges 120.31.19
On to B^2; W^2, 2 B^2 60. 0

Ship shifted.
Weighed B^2, and returned to ship.

8 Proceeded with B^2.
Moored B^3; 2 B^2, ship^3 ...... 59° 52′

To ship. J. S. L.

June, 1832.

$\triangle$ Tender. Observed 1st CUTTER shift Yellow Blue.

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6 Y B^2 and W. .... 60° 35′ 30″

Weighed and shifted to N.E. 2.30 moored.

Ship^2, 1 B. .... 28° 33′ 30″
Y B^2 .... 85.33.30

At—Observed R^2 moor.
R^2 and ship.............. 28.15.50
1 B............... 56.49.20

$\angle$s from mast-head.

Monkey-tree and ship	109° 41′
Pyramid and ship	107.41
Arrow clump and ship	106.20
Cotton clump	102.38
Wedge peak	98. 1
Umbrella-tree	90.11

At 12. 1 B weighed; do. 1.40 moored.

7 1 B^2 and ship^2............ 59° 16′ 43″
R^2 moored; 1 B^2, R^2...... 31. 0.45
Y B^3 moored; Y B^3, and 1 B^2 30.10.12

Weighed per signal, and shifted to eastward; 3. anchored and moored.
Ship not in sight.

Position $\triangle^2$.

R^3 and 1 B^2 .... 30° 35′ 55″
Y B^3 .... 60.38.30

$\angle$s to Land Objects.

S. tang. swamp sd. and 1 B^2	99° 48′
Middle Point do.	94.51
Pyramid	90.17
Monkey	89.30
Arrow	84. 5
N.W. tang. swamp Id.	80.27
Wedge peak	77.40
Cotton clump	77.30

Date.	June, 1832. △ Observed 1st CUTTER shift Yellow Blue—*continued.*	
	Tang. bend and 1 B²	74° 20′
	Umbrella tree	62.17
	Tang. trees	61.27
	Sand { Gull spit and inner tang. Island in line }	59.15
	Crab, and S.E. end gull in line.	56.50
	Gull knob { E.	55.55
	Gull knob { Centre	54.55
	Gull knob { W.	53 37
	Spire	54.19
	Abbey E. tang.	52.21
	Abbey	51.15
	Mangrove	49.30
	Curlew Patch { Sand	53. 0
	Curlew Patch { Bush	51. 0
	Curlew Patch { Centre	47.56
	Curlew Patch { Bush	46.15
	Curlew Patch { Sand	44.50
	Gull sand extremity	41. 0
	E. ape	44. 0
	West do.	38.40
	Water-tree	37.10

Date.	June, 1832. ∠s WHALER.	
6	Ship moored; proceeded to reef. Placed marks, and took angles from do. ∠s at white pendant. S.	
	1 B. and ship²	57° 55′
	Ship² and 2 B.	132. 5
	2 B. and W.	111. 0
	W. and 1 B.	59. 0
	W. and W. blue pendant W.	43° 55′ 0″
	Red S.	69 55
	B. W. E.	93.34
7	Ship moored after dark.	

Date.	June, 1832. ∠s WHALER—*continued.*	
8	A. M. Ship³. No sun.	
	1 B² and south tang. coast	37° 5′
	Monkey-tree (.)	37.39
	Pyramid (:)	41.15
	Arrow clump (..)	41.50
	Tang. point near	44.23
	Cotton clump (⁝)	45.19
	S. tang. sand, spit	57.35
	Wedge Peak	59.57
	Umbrella-tree (...)	61.57
	Centre low Island	66. 0
	Gull knob (1) { S. tang.	69.41
	Gull knob (1) { Centre	71.32
	Gull knob (1) { N.	73.41
	Crane-tree (new)	72.48
	S. tang. Abbey clump	75.15
	Abbey clump (—)	76.28
	Eagle Mount (new)	80.44
	Crab-tree (new)	82.10
	Mangrove (new)	89. 2
	Spire (new)	94.15
	Water-tree (new)	113. 0
	Ape's Hills E.	125.30
	W.	129.20
	Creek (S. point)	126.34
	Elephant	140.30
	Tang. trees	140.50
	Sand	144.49
	Left ship and crossed bar, landed on Gull Id.—Obtained sights, &c.	
	Theodolite, Zero=1 B².	
	Ship³	32° 4′ 0″
	Elephant	75.41.10
	West ape (alt. 0° 38′ 10″).	92.56.15
	East do. (alt. 0° 40′ 20″)	105.44.55
	Wedge (alt. 1° 40′ 30″)	250.17.35
	Umbrella	272.34.20
	Monkey	289.28.30
	△³	308.31. 0
	W³	18.32. 0
	R³	327.40. 0

No	Objects.	Angles.	Object.	Base. Feet.	Object.	Logarithms.	True bearing.	From which object.	Diff. Lat.	Diff. Long.	Latitude.†	Longitude.†
	Wh.	58°. 25′	Ship	30422.8	Red	4.483214	N 58°. 7′ . 9″ E	S	2′. 42″	4′. 25″. 8	11°. 27′. 52″ N	16°. 56′. 19″. 2
	Ship	61. 5	W	31261.2	R.	4.495005	S 58. 7 . 9W	W			11. 25. 10 N	17. 0. 45
1	Red.	40. 30	W	31083.7	S	4.492533	S 60. 47. 51W	S	2. 26. 4	4. 27. 0	11. 22. 43. 6	16. 56. 18
	Blue	61. 17	S	31083.7	W.	4.492533	N 0 . 26 . 9W	S	5. 3. 6	0. 2. 3	11. 30. 13. 4	17. 0. 47. 8
	Ship	58. 33	B	30236.3	W.	4.480528						
2	Wh.	60. 10	S	30746.0	B.	4.487788	N 61. 42. 51W	B	2. 21	4. 28. 2		
	Y B	60. 30	S	30422.8	R.	4.483214	S 1. 0. 51 E	S	4. 57. 6	0. 5. 4	11. 20. 12. 4	17. 0. 39. 6
	Ship	59. 47	Y.B.	30206.2	R.	4.480095						
3	R	59. 43	S	30185.7	Y B	4.479801	N 59. 29 . 9 E	Y B	2. 31. 2	4. 21. 6		
	1 B	59. 50	W.	31261.2	R.	4.495005	N 59. 42 . 9 E	R	2. 36. 2	4. 32. 8	11. 25. 19. 8	16. 51. 45. 2
	W	60. 10	1 B.	31366.4	R.	4.496464	S 60. 17. 51 E	1 B	2. 32. 4	4. 34. 2		
4	R	60. 0	1 B.	31314.0	W.	3.495737						
	W	61. 15	Blue	31090.3	2 B.	4.492626	S 0. 27. 51 E	2 B	5. 4. 2	0. 2. 5		
	2 B.	58. 30	Bl.	30236.3	W.	4.480528	N 58. 1. 51 E	B	2. 42. 6	4. 25. 8	11. 32. 56. 2	16. 56. 21. 5
5	B	60. 15	2 B.	30788.0	W.	4.488381						
	△	60. 13	Y B	30206.2	R.	4.480095	S 0. 7. 51 E	R	4. 57. 6	0. 0. 6	11. 17. 46	16. 56. 17. 4
	R	59. 37	Y B	30023.4	△	4.477460						
6	Y B	60. 10	R	30191	△	4.479878	N 60. 20. 51W	△	2. 26. 4	4. 22. 8		
	S		S	53961	2 B.	4.732080						
	2 B.		S	30746.0	B.	4.487788						
7	2 ba.	*	S	31083.7	W.	4.492533	N 28. 58. 52 E	S	7. 46. 2	4. 23. 4	11. 32. 56. 2	16. 56. 21. 6
	S		S	53648.5	1 B.	4.729558						
	1 B.		S	30422.8	R.	4.483214						
8	2 ba.	*	S	31083.7	W.	4.492533	N 88. 57. 9 E	S	0. 9. 6	9. 0. 0	11. 25. 19. 6	16. 51. 45
	S		S	52317	△	4.718644						
	△		S	30422.8	R	4.483214						
9	2 ba.	*	S	30185.7	Y B	4.479801	S 30. 35. 33 E	S	7. 24. 6	4. 28. 2	11. 17. 45. 4	16. 56. 16. 8
	S	59. 58. 17										
	1 B.	60. 18. 12	S	53961	2 B.	4.732080						
10	2 B.	59. 43. 31	2 B.	52557.2	1 B.	4.730635	S 30. 44. 39 E	2 B				
	S	60. 27. 18										
	1 B.	58. 32. 15	S	52317	△	4.718644						
11	△	61. 0. 27	△	53359	1 B.	4.727208	N 30. 24. 54 E	△				
	S^2	60. 13	W	31314	1 B.	4.495737	N 0. 50. 51W	1 B	5. 9. 6	0. 4. 6	11. 30. 29. 2	16. 51. 49. 6
	W	60. 10	S^2	31298.3	1 B.	4.495520						
12	1 B.	59. 37	W	31124.5	S^2	4.493102						
	S.^{2}	59. 32. 30	W	30788	2 B.	4.488381	S 61. 25. 21 E	2 B	2. 25. 2	4. 32. 4	11. 30. 31	16. 51. 49. 2
	2 B.	60. 37. 30	W	31124.5	S^2	4.493107						
13	W	59. 50.	2 B.	30880	S^2	4.489674						
	Y B^2	59. 8	R	31366.4	1 B	4.496464	S 1. 57. 51 E	1 B	5. 9. 6	0. 10. 6	11. 20. 10. 0	16. 51. 34. 4
	1 B.	61. 40	R	32164.4	Y B^2	4.507375						
14	R	59. 12	1 B.	31388.2	Y B^2	4.496766						
	Y B^2	56. 26. 30	R	30191	△	4.479878	N 62. 27. 39 E	△	2. 44. 6	4. 43. 2	11. 20. 10. 6	16. 51. 33. 8
	△	62. 35. 30	R	32163	Y B^2	4.507354						
15	R	60. 58	△	31677	Y B^2	4.500743						
	△^{2}	57. 0	1 B.	31388.2	Y B^2	4.496766	S 60. 27. 51 E	1 B	2. 44. 4	4. 56. 4	11. 22. 35. 2	16. 46. 48. 6
	Y B^2	64. 30	1 B.	33780	△^{2}	4.528663						
16	1 B.	58. 30	Y B^2	31911	△^{2}	4.503941						

* Derived from two bases.

† Lat. and Long. of objects in line on left column.

No.	Objects.	Angles.	Object.	Base. Feet.	Object.	Logarithms.	True Bearing.	From which object.	Diff. Lat.	Diff. Long.	Latitude.	Longitude.
	B^2	58°.55′	S^2	30880	2 B.	4.489674	N 0°.40′.11″W	S^2	5′.10″.8	0′. 3″.6	11°.35′.40″.0	16°.51′.53″.2
	S^2	60.15	2 B.	31305.	B^2	4.495608						
17	2 B.	60.50	S^2	31485.2	B^9	4.498106						
	W^2	59.48	S^2	31485.2	B^2	4.498106	N 59.21.49 E	S^2	2.37.8	4.33.6	11.33. 7.0	16.47.16.0
	S^2	60.12	B^2	31612.3	W^2	4.499856						
18	B^2	60.0	S^2	31549.0	W^2	4.498985						
	R^2	59.12	S^2	31298.3	1 B.	4.495520	S 60.55.41 E	S^2	2.32.4	4.39.6	11.27.56.8	16.47.10
	S^2	60.15	1 B.	31635	R^2	4.500166						
19	1 B.	60.33	S^2	31729.2	R^2	4.501458	S 0.50.40 E	S^2				
	R^2	59.56.39	S^2	31549	W^2	4.498985	S 1.09.02 E	W^2	5.10.2	0. 6.3	11.27.56.8	16.47. 9.7
	W^2	60.30.51	S^2	31729	R^2	4.501458						
20	S^2	59.32.20	R^2	31420	W^2	4.497205						
	1 B^2	59.28	R^2	31420	W^2	4.497205	S 60.50.05 E	W^2	2.33.0	4.40.2	11.30.34.0	16.42.35.2
	W^2	59.41	R^2	31490	1 B^2	4.498169						
21	R^2	60.51	W^2	31858	1 B^2	4.503220	S 59.41.57W	1 B^2				
	$\triangle^2$	61.6.55	S^2	54967	1 B^2	4.740103	S 31.54.16 E	S^2	7.53.4	5. 0.6	11.22.36.6	16.46.48.4
	1 B^2	60.12.50	S^2	56483,6	$\triangle^2$	4.751907	N 89.25.31 E	S^2	0. 5.4	9.14.4	11.30.35.4	16.42.34.6
22	S^2	58.40.14	$\triangle^2$	54617.5	1 B^2	4.737330	N 27.22.26	$\triangle^2$				
	2 B^2	60.21.48	S^2	54967	1 B^2	4.740103	N 29.03.31 E	S^2	7.49.8	4.26.4	11.38.19.8	19.47.22.6
	1 B^2	59.16.10	S^2	54360.7	2 B^2	4.735284	S 31.18.17 E	2 B^2				
23	S^2	60.22.2	2 B^2	54969	1 B^2	4.740119	S 89.25.31W	1 B^2				
	S^3	59.17	W^2	31450	2 B^2	4.497619	S 61.21.14 E	2 B^2	2.25.8	7.20.6	11.35.48.6	16.42.39.4
	W^2	60.43	S^3	31907	2 B^2	4.503892	S 59.21.46W	S^3				
24	2 B^2	60.0	W^3	31681	S^3	4.500801						
	2 B^2	60.31	B^2	31612.3	W^2	4.499856	N 59. 9.48 E	B^2	2.38.4	4.30.6	11.38.18.4	16.47.22.6
	B^2	60.0	W^2	31450	2 B^2	4.497619						
25	W^2	59.29.	B^2	31285	2 B^2	4.495334	S 1.21.14 E	2 B^2				
	R^2	57.27	$\triangle^2$	31383	Y B^3	4.496692	N 3.38.21W	$\triangle^2$	5.22.2	0.20.9	11.27.58.8	16.47. 9.3
	$\triangle^2$	61.11	R^2	32620	Y B^3	4.513491						
26	Y B^3	61.22	$\triangle^2$	32678	R^2	4.514252						
	W^2	59.48.9	1 B^2	31675.0	S^3	4.500718	N 60.50. 5W	1 B^2				
	S^3	60.22.35	W^2	31858	1 B^2	4.503220	N 1. 0.48W	1 B^2	5.13.2	0. 5.6	11.35.48.6	16.42.40.2
27	1 B^2	59.49.16	W^2	31681	S^3	4.500801						
	Y B^3	58.37.4	R^2	31490	1 B^2	4.498169	S 2.28.19 E	1 B^2	5.12.6	0.13.7	11·25.22.8	16.42.20.9
	1 B^2	62.10.15	R^2	32620	Y B^3	4.513491						
28	R^2	59.12.41	Y B^3	31687	1 B^2	4.500881						
	B^3	59.52	S^3	31907	2 B^2	4.503892	N 1.11.14W	S^3	5.15.6	0. 6.6	11.41. 4.2	16.42.46.6
	S^3	60.10	2 B^2	32004	B^3	4.505204	S 57.21.21 E	2 B^2				
29	2 B^2	59.58	B^3	31940	S^3	4.504331						
	W^3	59.20	S^3	31675	1 B^2	4.500718	S 57. 4.56 E	S^3	2.33.6	4.43.2	11.33.15.0	16.37.56.8
	S^3	60.0	1 B^2	31891.5	W^3	4.503675	N 1. 0.47W	1 B^2	5.12.6	0. 5.6	11.35.48.6	16.42.40.2
30	1 B^2	60.40	S^3	32103.6	W^3	4.506553						
	R^3	60.33	1 B^2	31687	Y B^3	4.500881	S 62.25.17 E	1 B^2	2.23.4	4.40.2	11.28.12.0	16.37.54.4
	1 B^2	59.57	Y B^3	31498	R^3	4.498282						
31	Y B^3	59.30	1 B^2	31354	R^3	4.496290	S 2.28.18 E	1 B^2				
	R^3	61.55	1 B^2	31891	W^3	4.503675	S 0.30.19 E	W^3	5. 2.4	0. 2.7	11.33.14.4	16.37.57.1
	1 B^2	57.55.29	W^3	30630	R^3	4.486140						
32	W^3	60. 9.31	1 B^2	31354	R^3	4.496290	N 59.39.12 E	S^3				

No.	Object.	Angles.	Object.	Base Feet.	Object.	Logarithms.	True Bearing.	From which object.	Diff. Lat.	Diff. Long.	Latitude.	Longitude.
33	$\triangle^3$	60°.38′.30″	Y B^3	31498	R^3	4.498282	S 61°.24′.18″ E	Y B^3	2′.24″.3	4′.30″.6	11°.22′.58″.8	16°.37′.50″.3
	R^3	57.47.30	R^3	30578	$\triangle^3$	4.485409						
	Y B^3	61.34. 0	R^3	31780	$\triangle^3$	4.502152						
	$\triangle^3$	30. 2.35	1 B^2	31687	Y B^3	4.500881	S 31.21.43 E	1 B^2	7.37.2	4.44.4	11.22.58.2	16.37.50.3
	1 B^2	28.53.25	$\triangle^3$	30578	Y B^3	4.485409						
34	Y B^3	121. 4. 0	1 B^2	54213	$\triangle^3$	4.734105						

LAND OBJECTS.

MONKEY STATION.

1	Mon	28.29	$\triangle^2$	56483.6	S^2	4.751904	N 77.16.44 E	$\triangle^2$	2.45.0	12.57.6	11.25.21.6	16.33.50.8
	S^2	41.50	$\triangle^2$	78991	Mon	4.897578						
	$\triangle^2$	109.41	S^2	111.513.6	Mon	5.047326	From ship					
							S 73.45.16 E		5. 8.4	17.58.2	11.25.20.8	16.33.51.4

UMBRELLA TREE.

2	Umb	29.51	$\triangle^2$	56483.6	S^2	4.751904	N 88. 7.44 E	S^2	0.36.6	19.3.0	11.31. 5.8	16.32.46.6
	S^2	59.58	$\triangle^2$	98241.5	Umb	4.992294						
	$\triangle^2$	90.11	S^2	113477	Umb	5.054907						

FOR MONKEY.

3	Mon	63.59	$\triangle^3$	54213	1 B^2	4.734105	S 57.43.43 E	1 B^2	5.18.0	8.33.6	11.25.17.4	16.34.1
	1 B^2	26.31	$\triangle^3$	26933	Mon	4.430287						
	$\triangle^3$	89.30	1 B^2	60324	Mon	4.780489						

FOR UMBRELLA TREE.

4	Umb	56.35	1 B^2	54213	$\triangle^3$	4.734105	N 87.30.17 E	1 B^2	0.24.7	9.39.0	11.31. 0.1	16.32.55.6
	$\triangle^2$	62.17	1 B^2	57498	Umb	4.759651						
	1 B^3	61. 8	$\triangle^3$	56880	Umb	4.754959						

FOR GULL KNOB.

5	Gull	51.29	1 B^2	54213	$\triangle^3$	4.734105	N 75. 2.57 E	1 B^2	2.24.5	9.12.0	11.33.00.6	16.33.22.6
	1 B^2	73.36	$\triangle^3$	66470	Gull	4.822622						
	$\triangle^3$	54.55	1 B^2	56700	Gull	4.753583						

FOR ELEPHANT.

6	Ele.	49.36.31	1 B^2	54969	2 B^2	4.740119	N 22. 6.17 E	1 B^2	10.43.2	4.26.7	11.41.18.6	16.38. 7.8
	2 B^2	76.58.55	1 B^2	70317	Ele.	4.847063						
	1 B^2	53.24.34	2 B^2	58071	Ele.	4.763960						

WEDGE PEAK.

7	Wed	49.15	1 B^2	54213	$\triangle^3$	4.734105	S 84.26.43 E	1 B^2	1. 6.8	11.41.4	11.29.28.7	16.30.53.2
	1 B^2	53. 5	$\triangle^3$	57215	Wed	4.757509						
	$\triangle^3$	77.40	1 B^2	69911	Wed	4.844545						

APE MOUNTAINS (E.)

8	E.A.	35.25.31	1 B^2	54969	2 B^2	4.740119	N 36.53.17 E	1 B^2	12.8.4	9.16.8	11.42.43.8	16.33.17.8
	1 B^2	68.11.34	2 B^2	88047	E.A.	4.944713						
	2 B^2	76.22.55	1 B^2	92167	E.A.	4.964576						

WEST APE.

9	W A	40.47.31	1 B^2	54969	2 B^2	4.740119	N 31.53.17 E	1 B^2	11.24.6	7.15.0	11.42. 0.0	16.35.19.6
	1 B^2	63.11.34	2 B^2	75096	W A	4.875619						
	2 B^2	76. 0.55	1 B^2	81645	W A	4.911930						

Explanation of the work of the 6th June. The astronomical bearing of the △ gives S. 31° 54′ 16″ E., which differs only 11″ from that by the previous work.

	Thus the true bearing of the 1st barge from ship	=	$\frac{N}{S}$ 88° 57′ 9″ $\frac{E}{W}$
30. 35 } 59. 37 }	Angle to white + ship	=	90 12 0
	True bearing of ship	=	179 9 9
			$\frac{N}{S}$ 0 50 51 $\frac{W}{E}$
	∠ 1 barge to $\triangle^2$	=	31 3 36
	= true bearing of $\triangle^2$	=	S. 31 54 27 E.
	By observation 6th	=	31 54 16

The tender and beacons then have advanced,—land has been seen from ship and tender—and the astronomical bearings determined from the extremity of one of the main bases.

The object now becomes one which requires consideration. The ship, tender, and barges, are to enter the port if possible, to refit and pursue astronomical details. This, like chess, should be done without *losing a move*—and, moreover, so that the positions, after the internal survey is concluded, may be expeditiously and satisfactorily resumed. The changes will then be as follows—

1st.	1 B^2 to the equilateral on	W^2 R^2
2nd.	2 B^2 . .	$Blue^2$ W^2
3rd.	Y. B^3 . .	R^2 $\triangle^2$
4th.	$Ship^2$ . .	1 B^2 W^2 2 B^2
5th.	W^2 . .	$Ship^3$ 1 B^2
6th.	R^2 . .	1 B^2 Y. $B.^3$
7th.	$\triangle^2$ . .	R^3 Y. $B.^3$ (as most convenient for ∠s and ground.)
8th.	B^2 . .	2 B^2 $Ship^3$

Now, it will be apparent that these beacon positions are competent to fix any external objects, and at low water (should the tide fall above ten feet) two will be seen , (10 miles, or 8′ plainly,) and may be taken by the theodolite from some of the fixed stations on shore. Thus then, in *resuming* positions ; the respective instructions would be, " You will resume position on the line , and in one, angle to ."

We will now lay off the work for the 7th June, in the same order as above.

The angles taken at the ship, tender, and barges, are sufficient to determine the external features and main positions, which have been duly calculated and placed on the chart, in latitude and longitude;

thus obviating the errors which long lines might produce. We will suppose then, that the ship, tender, and boats, have anchored within, and that by a series of astronomical observations, the latitude as determined at sea, is found to be correct; and the longitude a few seconds out.

This would be immediately obviated by shifting the meridians and parallels, the ruling of which in ink should be deferred until the last moment, as the mere working on the paper may materially warp the lines.

The work of the internal survey not differing from that of a Port conducted on shore, will not be dwelt on here. The "*River Survey*" will be separately entertained. We will therefore proceed to point out, what will be expected before quitting this port,—now one of importance, as a first determined position. As a formula will now clearly show the desiderata, it will be introduced for this purpose.

Positions.	Latitude.	Longitude.	Variation.	Dip.	TIDES.				Specific Gravity.		Elevation above sea.
					H. W. full & change	Rise springs	Neaps.	Greatest velocity.	Turn of Ebb.	H. W.	
Gull Knob	11° 33′ 00″.0	16° 33′ 22″.6	19° 27′ 0″	Could not be determined.	2.30	18 ft.	9.6	3,2	1010.7	1027.7	30.0
East Ape	11.42.43.8	16.13.17.8									797.88
West Ape	11.42. 0.0	16.35.19.6		Station basalt.							713.1
Wedge	11.29.28.7	16.30.53.2									806.6
Elephant	11.41.18.6	16.38. 7.8									
Umbrella	11.31. 0.1	16.32.55.6									
Monkey	11.25.17.4	16.34. 1									
Wreck Island (Centre.)			19.30.30			17′.2		2			10 ft. (low water.)

Next. Observe the depths running out and in on *particular objects in line*, and class them for constructing "Sailing Directions," which is one of the most important points of a surveyor's duty; and where he has himself performed his work, one of the most gratifying sources, when he finds "*land marks*," (cross lines of direction,) bear out those originally laid down by instruments. The nature of every position he lands at should be examined, and specimens, not loose and rubbly, but of the interior of the *abounding rock*, carefully preserved

and labelled. Water he never should neglect to insert on his chart, and every observation on its quality and effect on his crew should be entered in his remarks. The produce, as regards the wants of man, prices, &c.; timber, as fuel, or adapted to building, and its durability. In treating of fuel, he should distinctly ascertain whether it is preferable to obtain it from the natives, or employ his own crew; and if the latter, how far they may be subject to contract disease by being thus employed. The first duty being the preservation of life at *any cost*, no other consideration should be allowed to interfere on this point. In his communications with the inhabitants he should endeavour to collect every peculiarity in their habits; as to herbs used for medicine, such as may *safely* be used for the support of animal life, dyes, manufactures, implements of husbandry and methods of cultivation, peculiar methods of cooking, and particularly those which may conveniently be adopted by persons whom shipwreck may throw on their own resources. He never should neglect to impress them with a due sense of the power and *kindness* of his nation, and that relief to its natives in distress will be sure of recompense. Their religion and modes of worship, and the dangers of improper interference, or how they may be conciliated. The surgeon should be frequently introduced amongst them, and endeavour to render every assistance, in healing disease; which service is one of the strongest inducements among savage tribes to preserve friendship. A collection of seeds, roots, plants, &c. should be made, if possible; and such as appear uncommon, preserved dried between paper. The resources the country affords in a commercial view. The capabilities in a warlike position, either for attack or defence, and how it may most safely be attacked or defended, should *he* be placed in the situation of an enemy. This should never be lost sight of by the surveyor in visiting any part of the world; and should he be of an enterprising character, he should ever bear in mind that such knowledge may give him a preference to conduct services of this nature.

We will now resume our work outside. Hitherto we have advanced in force, but having determined positions on shore, which cannot shift, we may conveniently divide our forces, and pursue (if called for) the completion of the Peninsula, or whatever it may be. We will, therefore, merely point out how this may be conveniently effected, without involving further angles or calculations.

In the northern expedition we shall take ship, 1st barge, 1st cutter, and B. and W. beacons. Then, Let 1 B. take up the old position

S^3, having W^3 and wedge peak in line, and nearly similar angles from ship to land objects as when she occupied that position.

Then ship at S^a, B^3 and 1 B^3 in line, fixed by land objects.

Shift W^3 to W^a, fixed same.

1 B^3 to 1 B^a, W^a and elephant in line.

S^a to S^b, W^a and B^3 in line. (Thus, B^3 is still in position.)

N. B. In taking up these positions 1 B^3 would of course, as well as $\triangle$, be verified by theodolite from Gull.

Southern Expedition.—Tender; 2 B.; 2 cutter; 2 beacons. (Red and Y. B.)

$\triangle$ would resume her old position, W^3 R^3 in line, angles to Y. B. and land objects.

R^3 to R^a; 2 B to 2 B^a; Y B^3 to Y B^a.

Thus, it will be apparent, that in conjunction with the land, two vessels and two beacons can get on rapidly.

By the method thus described the coast is trigonometrically laid down, and all dangers placed to the utmost nicety. Coast surveys (when no intricate channels are involved, or dangers numerous) are conducted by the day's run, the bases being measured by the patent log., and the main positions fixed by the astronomical observations on board, which will be hereafter treated of.

River Survey, Plate VII.

We will now proceed to describe the operation of a "flying survey" by boats, in the examination of a river into which the ship cannot conveniently be brought; the determination of its course and extension into the interior, being the principal object to be attained.

We will suppose the river to be muddy, and overhung by mangrove, so that a survey cannot be carried on by landing; and that it is required to perform this operation *accurately* and *rapidly*.

Our establishment then consists of two barges, two cutters, five gigs,—in all nine. Each boat takes her distinguishing flag, and the same equipment as before noticed. She must also carry her proportion of uncooked provision, making her own arrangement with the barge to which she will be attached; viz. 1 cutter, whaler, 1 gig, jolly, at 1 barge; the others at 2 B.

The general order to be understood by all is—"That when a boat is signalled "*advance*," she, without hesitation, makes the best of her way (for convenient lines of sounding) to a position in advance, on

an angle of not less than 50°, if possible, with the advanced objects, "*barges not included.*" The barges are subject to special directions, and are reserved for the long legs of *direction* and *verification.* The principal will so manage his movements, that he will be generally above the mooring boat, so that each boat in passing him will receive her final or special instructions, as to what objects are fixed, or what lines of soundings omitted; and where he finds the bends of the river untoward, take up an auxiliary position to prevent loss of time.

It should be clearly understood, that no boat can move from her position until three above her are moored, and have shown the signal that all "angles have been taken." In taking up positions, some little experience on this point has shown me, that even on this simple subject much valuable time is saved by working by method. If the tide be rising, give the boat full way stem on to the mud, and the station is instantly fixed, but must be *maintained* by oars into the mud supporting stem, and the quarter similarly steadied. With a falling tide a very different method must be adopted. On such service each boat has her pair of anchors and buoy ropes. In running for the station, drop the anchor with scope to reach the shore; pass one end of the buoy rope round a tree, and back to the boat, bowse off on the cable, so as to be safe from grounding. Sometimes the lead thrown over a bough, and hooked back by the boat-hook, will answer this purpose; but in such case the anchor should be well up the stream, and the boat well steadied by oars. When it is considered how many others are, probably, awaiting with impatience the movements of one, I may perhaps be excused for being thus minute; but without *method*, without some *decided* system which shall satisfy the principal that the labour and fatigue which is undergone by all, is to be of *value*, he cannot proceed. On him rests the *care*, and it is his duty to see that all is secure before he makes a move in advance. It is almost incredible what can be achieved in one day, where the work is fairly conducted; and with what satisfaction each individual, even the seamen themselves, talk over their manœuvres.

In the plan introduced to explain this work, five moves only of each boat have been projected, and I doubt not but those who practise on those angles will think they were alone sufficient for the day. But they will, perhaps, scarcely credit that five boats (barges not included) in one day took up fifteen positions each, making altogether, with the barges, ninety-six stations in fifteen miles.

The first positions are to be derived from fixed stations,—from the exterior survey, if possible,—and we will therefore suppose Mosquito and Rocky stations to be two such. In placing the barges, it is advisable to get them on the longest legs, and to command as many positions as possible, as their angles give the direction of each boat at once. The 1 B. occupies the first position, and is fixed from the stations on shore; the 1 C. takes up next; then 2 C.; then whaler; and by these the position of, and long leg to, 2 B. is completed. The other boats take up in their order; and the three gigs being secure, all boats below the 2 B. advance. In doing so, they sound diagonally across the river to the "next a-head."

If the river, therefore, was equally wide throughout, and not very serpentine, such lines would be nearly parallels. But considering the object of such a survey, and the rapidity requisite, it will be found that such traverses display a fair proportion of soundings. (The lines of soundings have only been inserted on the first moves, as they rather interfere with the object of the plan, which is principally to show the method of advancing the triangles.) In taking up the positions of the barges, it should always be a main consideration to preserve some original *land-mark*. Thus, in the plan, "Spire" is seen from the greater part of the stations, and in the protraction affords great facility in securing the main positions by the back angle. It is evident that the whole series of triangles may be worked out if an important position be required. This is materially facilitated by the long legs, if a third land object can be brought in aid. For instance, the long legs 1 B. and 2 B at their first positions, and 2 B. and 1 B.^{2} may be determined. But the spire is obtained in three triangles from the 2 B., and quite secure at the fourth triangle above her, just at the very moment that four insignificant triangles might vitiate the position of the 1 B.^{2}

Now in working for latitude and longitude, the simplest method is to take the *great* triangles. For instance, Mosquito to 2 B., 2 B. to 1 B.^{2} [*determined from spire*; because the angles at 2 B. and 1 B.^{2} being known, that at spire must result; and it being fixed from 1 C.^{2} will secure 1 B.^{2}] In that triangle the distance from spire to 1 B.^{2} is found. The angles are known, therefore 2 B.^{2} is known for the next great triangle. The 1 B.^{3} position is similarly obtained, also the 2 B.^{3} Now the positions 1 B.^{3} and 2 B.^{3}, if in doubt on the *protraction*, could have been verified: thus, the leg spire 2 B. is known, and spire to 1 B.^{3} and 2 B^2, and the included angles corresponding; therefore the

direct lines from the first position of 2 B. could have been gained by the simple problem—" Having the legs and included angle, to find the other angles."

And at length, having by plane trigonometry gained the angles and distances, the great triangle 2 B ³ spire and Mosquito is complete. Therefore the true bearings and distances of these objects from the primary station becomes a very simple operation, and the numerous minor triangles serve to complete the detail and lay down the soundings.

This Spire, however, is a convenient object; in nine cases out of ten the small triangles *alone* perform the work, as the high overhanging trees prevent inland objects from being available.

This central object, or " Object of Reference," has been purposely introduced, because by such means alone we are frequently compelled to gain our stations on forbidden ground, as will be more apparent when we come to treat on Harbour Survey.

We will suppose, however, that this river is to be protracted solely on its minor triangles, using the barges only as " lines of direction." Before commencing, carefully go through the documents, and if possible, make the individuals *read* their *own* angles in the order in which they proceeded, and tabulate them, as in that marked A. Any irregularity or error in copying from the rough books is thus obviated. Those who have puzzled themselves over the documents of others, will readily feel the situation. The principal, or the person who may protract from such, will feel satisfied that his labour is not to be in vain.

By this method also, each set of moves may be taken as a separate practice for the young beginner. Thus, calling the base on which he commences (say jolly 3 gig) 3000 feet, let it be required to determine the position J^2. 3 G^2. in lat and long., the starting point being J. = 10° 20′ 40″ N. long. 16° 2′ 20″ W.

Also the position of the spire, and resolve it into one great triangle on J. J^2.

Enough, I trust, has been said to show that such surveys can be achieved with very great nicety, provided a small portion of zeal be found amongst the parties engaged.

There is also another method employed,—the track survey of rivers, but which is liable to objection from the very uncertain velocity in different parts of the stream. This is conducted by making use of the ground log to determine the rate of progress over the ground. The

lead line is used for this purpose, and a certain number of fathoms being allowed for stray, the number of fathoms run off in a given interval, measured by watch, is taken as the speed of the vessel. If the boats be made to precede the vessel by a day, and be stationed in all the long reaches as distinct marks to steer to, and bases by sound be measured, this might be brought nearer to the truth, as the boats, being stationary, would have leisure to take the requisite angles to the tangents above and below. When it is considered that the reaches not unfrequently are at east and west bearings, the local attraction alone, unless Barlow's plate be used, and very nicely adjusted, would create no trifling error in high latitudes. Indeed, wherever the compass enters into operation on shore or afloat, I am particularly averse to giving any weight to the results. When time cannot be spared, such, however, should not be neglected, but they should be denoted as "Track Survey, dependent on magnetic bearings." Such a survey, when astronomical observations can be obtained at the intermediate or extreme stations, is of importance in a geographical point of view, and serves to correct the many imperfections which exist in maps of countries little visited, or inhabited by uncivilized beings.

TABULATION OF THE TRIANGLES.

1st Triangle—1 B. Mosquito 52° 30′ Rocky .. 50.45 1B. 76.45	2nd.—1 C. Mosquito 50° 51′ 1 B. .... 78.50 1 C. 50.19	3rd—W. 1 C. .... 51° 47′ 2 C. .... 88.22 W. 39.51	4th—2 B. 1 C. .. 121° 20′ 1 B. .. 40.11 2 B. .. 18.29	5th.—2 B. 1 C. .. 21° 28′ W. .... 128. 2 2 B. .. 38.30
6th.—1 G. W. .... 117.36 1 C. .. 21.28 1 Gig.. 40.56	7th.—2 G. W. .... 26.43 1 G. .... 74.49 2 G. 81.28	8th.—3 G. 2 G. .... 81.58 1 G. .... 45.37 3 G. 52.25	9th.—J. 3 G. .. 114.40 1 G. .. 32.57 J. 32.23	10th.—1 C.^{2} 1 G. .. 23.32 3 G. .. 112.25 1 C.^{2} .. 44.03
11th.—2 C.^{2} 1 C.^{2} .. 112.23 2 G. .. 17. 7 2 C.^{2} .. 50.30	12th.—W.^{2} 2 C.^{2} .. 22. 6 1 C.^{2} .. 56.40 W.^{2} .. 101.14	13th.—1 G.^{2} W.^{2} .... 48.27 2 C.^{2} .... 80.54 1 G.^{2} 50.39	14th.—2 G.^{2} 1 G.^{2} .. 71.30 W.^{2} .... 56.16 2 G.^{2} 52.14	15th.—J.^{2} 2 G.^{2} .. 54.40 1 G.^{2} .. 75.30 J.^{2} 49.50
16th.—3 G.^{2} J.^{2} ...... 91.15 2 G.^{2} .. 39.57 3 G.^{2} .. 48.48	17th.—1 C.^{3} 2 G.^{2} .. 18.42 3 G.^{2} .. 117.38 1 C.^{3} .. 43.40	18th.—2 C.^{3} 2 G.^{2} .... 42.40 1 C.^{3} .... 86.15 2 C.^{3} 51. 5	19th.—1 G.^{3} 3 C.^{3} .... 56.37 1 C.^{3} .... 73.45 1 G.^{3} 49.38	20th.—W.^{3} 2 C.^{3} .... 39.18 1 G.^{3} .... 82.18 W.^{3} 58.24
21st.—3 G.^{3} 1 C.^{3} .. 27.30 W.^{3} .... 113.16 3 G.^{3} .. 39.14	22nd.—J.^{3} 3 G.^{3} .. 85.37 1 G.^{3} .. 30.40 J.^{3} 63.43	23rd.—1 C.^{4} 3 G.^{3} .... 59.19 J.^{3} .... 50. 4 1 C.^{4} 70.37	24th.—Solitary. 1 C.^{4} .... 55.47 J.^{3} .... 64.58 Solitary . 59.15	25th.—2 C.^{4} Solitary . 83.15 1 C.^{4} .... 53.43 2 C.^{4} 43. 2
26th.—2 G.^{3} 1 C.^{4} .... 61.34 2 C.^{4} .... 60.13 2 G.^{3} 58.13	27th.—W.^{4} J.^{3} .... 33.24 2 C.^{4} .... 94.30 W.^{4} 51.56	28th.—1 G.^{4} 2 C.^{4} .... 51.24 W.^{4} .... 77.10 1 G.^{4} 51.26	29th.—3 G.^{4} W.^{4} .... 50.30 1 G.^{4} .... 78.42 3 G.^{4} 50.48	30th.—J.^{4} 3 G.^{4} .... 81.10 1 G.^{4} .... 47.40 J.^{4} 51.10
31st.—2 G.^{4} J.^{4} .... 58.42 3 G.^{4} .... 69.50 2 G.^{4} 51.28	32nd.—2 C.^{5} 2 G.^{4} .... 84.54 J.^{4} .... 49.29 2 C.^{5} 45.37	33rd.—1 C.^{5} 2 C.^{5} .... 70.57 2 G.^{4} .... 42.57 1 C.^{5} 66. 6	34th.—1 G.^{5} 1 C.^{5} .... 64.31 2 C.^{5} .... 48. 0 1 G.^{5} 67.29	35th.—W.^{5} 1 G.^{5} .... 66.56 2 C.^{5} .... 59.50 W.^{5} 53.14
36th —3 G.^{5} 1 G.^{5} .... 63.37 W.^{5} .... 64.48 3 G.^{5} 51.35	37th.—J.^{5} W.^{5} .... 34.55 3 G.^{5} .... 95. 7 J.^{5} 49.58	38th.—2 G.^{5} 3 G.^{5} .... 48.31 J.^{5} .... 80.50 2 G.^{5} ... 50.39		

June, 1832.
FIRST BARGE.

Date.		° ′
10	Moored in position.	
	Mosquito and Rocky Stations..	76. 45
	1 C. moored ; 1 C. and Mosquito	78. 50
	2 C. moored ; 2 C. and 1 C...	43. 5
	Oyster and 2 C...............	20. 36
	2 C. and 2 B................	2. 54
	Creek 14. 40 to......	17. 20
	Whaler.............	43. 0
	1 C. and tang. Alligator Pt....	53. 55
	Mosquito Island 65. 30 to.......	81. 55
	Mosquito and tangent RockyPt.	73. 0
	1 B^2.=2nd Position.	
	2 B. and Crane.............	3. 40
	W^2...........	5. 41
	Heron..........	7. 42
	2 G^2...........	46. 24
	2 C^2........2 B.............	21. 30
	1 G^2....... ,, ...	29. 47
	Spire....... ,, ...	34. 37
	3 G^2....... ,, ...	61. 15
	2 C^3....... ,, ...	78. 52
	Crab ...... ,, ...	80. 00
	2 B. shifted to 2 B^2, E. by N. and moored.	
	2 B^2 and spire..............	46 38
	3 G^3.... ,,................	47. 38
	J^2 and 2 C^3...............	34. 35
	Shifted to 1 B^3.	
	1 C^4 open right 5′.	
	Spire and 2 B^2..............	40. 20
	Eel ,, ...	5. 30
	3 G^4 ,, ...	10. 30
	2 G^4 ,, ...	66. 45
	2 B^2 ,, W^4............	26. 32
	,, ,, 1 G^4..........	52. 33
	2 B^3, moored N.N.W.	
	2 B^3 and spire..............	87. 10
	W^5..............	2. 24
	2 C^5............	18. 15
	2 G^4..............	60. 45

June, 1832.
SECOND BARGE.

Date.		° ′
10	Moored; 1 C. moored ; 1 C, 1 B.	18. 29
	Whaler moored—whaler and 1 C	30. 30
	1 C, and 1 G.........	135. 40
	Knob........	22. 5
	Crane........	74. 5
	2 Gig, moored.	78. 0
	Heron........	81. 0
	3 Gig, moored.	100. 2
	Spire.........	107. 30
	Mosquito stat. and 1 B.......	15. 19
	1 B. weighed and shifted to southward, ditto moored.	
	Mosquito and 1 B^2...........	81. 29
	Heron........	78. 11

June, 1832.
SECOND BARGE—*continued.*

Date.		° ′
10	Mosquito and W^2............	79. 39
	2 B.—No. 2.	
	Shifted up river to south-side.	
	Spire and 1 B^2..............	46. 57
	Crab 1 B 2...............	5. 43
	1 B^2 and 1 C^3...............	7. 50
	1 G^3.............	31. 50
	W^3...............	50. 40
	1 G^3 and 3 G^3...............	101. 13
	Solitary and 1 B^2...........	90. 21
	J^3 and 1 B^2................	57. 37
	1 B shifted up river.	
	1 B^3 and 2 C^4...............	5. 43
	Spire................	78. 9
	Shifted up.	
	2 B.—No. 3.	
	1 G^5 moored, J^5	34. 16
	1 B^3, J^4, and 1 G^4 in line, to 1 G^5	22. 25
	3 G^4............ 1 B^3	14. 2
	Eel .... ,, ...	15. 10
	2 G^4............ ,, ...	28. 25
	2 C^5............ ,, ...	32. 25
	Spire .... ,, ...	54. 25
	W^5 and 2 C^5...............	90. 54
	J^5 and 2 G^5...............	17. 48
	3 G^5.................	38. 10

June, 1832.
WHALER.

Date.		° ′
	Landed at Mosquito station, 1 B moored.	
10	Rocky Pt. station and 1 B	52. 30
	Oyster	66. 14
	2 C........	86. 50
	1 C........	103. 23
	Knob	91. 54
	Tangent Pt.	92. 44
	2 B........	98. 13
	Proceeded to Rocky Point Station.	
	Tangent trees and 1 B....	3. 0
	of creek ,,......	38. 0
	1 B. and Mosquito...........	50. 45
	1 B and Tangent Mosquito....	57. 55
	Took up position on N. Bank, moored.	
	1 C. and 1 B...............	15. 0
	2 C...............	39. 38
	2 B...............	120. 2
	Tangent Mangrove Pt.	15. 30
	Oyster	26. 30
	Knob	60. 54
	1 G. moored ; 1 C. and 1 Gig..	117. 36
	2 G. ,, 2 Gig..	90. 53
	3 G. moored ; 1 C. 3 Gig (spire in line.)	95. 32
	2 B........	120. 2
	Crane......	87. 40

June, 1832. WHALER—*continued.*

Date.			
10	Shifted to W^2 intermediate or connecting station.		
	Sounded to 2 B.; 2 . 2½, 3, 4, 3, 2½, 2 . 1½ ; at 2 B. towards spire, 2 . 3, 4½ 4, 5 . 4½, 4, 3 . 3 . 2½ 2 . 1 ashore. To Jolly, 2½ . 3 . 4, 5, 4½, 4 . 3 . 2½ 1. To 2 C^2, 2 . 2½, 3, 4 . 3½, 3, . . 2½ . 3, 2, 1. To station, 2 . 3, 4 . 3. 2½, 2, 1.		° ′
	2 $C^{(2)}$ moored, and 1 C^2	....	101. 14
		Spire	19. 15
		Hawk	73. 30
		Crane	94. 5
	1 G^2 and	2 $C^{(2)}$	48. 27
	$J^{(2)}$,,	....	65. 50
	1 B^2 ,,	....	82. 55
	2 $G^{(2)}$,,	....	104. 33
	$W^{(3)}$ Crab and Spire in line, moored S.		
	2 C^3,	3 G^2......N.	16. 22
		1 G^2......N.	21. 10
		1 C^3...... S.	32. 28
		1 $G^{(3)}$.... S.	58. 24
	Spire and	2 $C^{(3)}$.......	12. 12
	J^3 ,,	,, ...	44. 33
	3 G^3 ,,	,, ...S.	80. 48
	2 B^2 ,,	,, ...S.	75. 3
	1 $C^{(4)}$,,	,, ...S.	72. 55
	1 B^3 ,,	,, ...S.	71. 41
	Eel ,,	,, ...	69. 55
	2 $C^{(4)}$, moored	,, ...	68. 36
	Solitary (Id.)	,, ...	52. 36
	3 G^3 and	J^3	36. 17
	∠s on Solitary.		
	W^3 and	1 C^4........	44. 0
	2 B^2 ,,	....	27. 20
	J^3 ,,	....	59. 15
	1 C^4 and	2 C^4.........	83. 15
		Eel..........	90. 2
	W^4.		
	2 C^4 and N. tangent solitary...		22. 0
		Centre	31. 30
		S. tangent....	37. 45
		J^3	52. 9
		Spire........	31. 12
	3 G^4 moored,	2 C^4.........	26. 40
	Eel ,,	,, ...	18. 1
	1 G^4 ,,	,, ...	77. 10
	1 B^3 ,,	,, ...	49. 42
	J^4 ,,	,, ...	46. 55
	1 G^5 and 1 C^5 in line	,, ...	41. 57
	W^5.		
	2 C^5 and	3 G^4	14. 14
		1 B^3	28. 29
		J^4	28. 44
		1 C^5	33. 39
		1 G^5	53. 14
	1 G^5 and	J^5..........	29. 53
		2 B^3.........	35. 55
		2 G^5.........	47. 2
		3 G^5	64. 48

June, 1832. FIRST CUTTER.

1st Station on N. Shore.

Date.			° ′
10	Mosquito and Rocky	....	38. 2
		1 B	50. 19
	2 C. moored; 1 B. and 2 C	...	90. 48
		1 B. and oyster..	35. 18
		Knob ..	107. 17
		2 B....	121. 20
	1 Gig moored; 1 G. and 2 B	....	9. 20
10	Whaler moored; 1 G. whaler	..	30. 55
		1 C. ,, ...	51. 47
	Tang. Alligator Pt. and 1 B.		61. 38
		Mosquito Is. ,, N.	60. 21
		,, S.	48. 10
		Rocky Pt. ,, .	14. 25
	1 B. and tangent Knob Pt	......	108. 40
	Shifted to N. above Jolly—Sounded to 1 B. 1½ 2 . . 3 . 5 . 4 . 3 . . 2½ . . 2 . . to 2 G. 3 . . 4½ . 4 . . 5 . 4 . 3 . 2 . . to 3 G. 3 . . . 4½ . 4½ . 2 3 . 4 . 2½ to station 3½ 4 . . 3½ 3 . 2 . 1 moored.		
	1 C^2		
	2 $C^{(2)}$ moored; 1 Gig and J.	..	44. 3
		Spire	110. 32
	,,	1 Gig	66. 35
	,,	2 Gig	82. 55
	,,	Hawk	59. 30
	2 $C^{(2)}$ moored, and spire	......	30. 30
	1 $Gig^{(2)}$ moored,	,, ...	63. 31
	W^2 ,,	,, ...	86. 8
	1 B^2 ,,	,, ...	89. 23
	1 C^3		
	3 G^2 and	2 G^2	43. 40
		1 G^2	21. 30
	2 C^3 ,,	3 G^2.........	86. 15
	Crab ,,	,, ...	96. 25
	2 B^2 ,,	,, ...	107. 50
	3 G^3 ,,	,, ...	110. 5
	W^3 and	2 C^3.........	51. 30
	1 G^3 ,,	,, ...	73. 45
	W^3, and	3 G^3.........	27. 30
	1 C^4		
	J^3, and	1 G^3.......S.	46. 23
		$W^{(3)}$...... S.	59. 51
		3 $G^{(3)}$..... S.	70. 37
	Solitary and	J^3	55. 47
	E. tangent do..	,, ...	68. 5
	W. do........	,, ...	39. 30
	2 C^4.........	,, ...	109. 30
	2 G^3 (over bushes) and J^3.	....	47. 56
	2 C^4 and 2 G^3	....	61. 34
	1 C^5		
	2 C^5 and 2 G^4	....	66. 6
	2 G^4 and 3 G^4	....	38. 5
		W^4..............	49. 23
	W^5 and 2 C^5	....	38. 34
	2 B^3 and 2 G^4	....	108. 21
	1 G^5 and 2 C^5	....	64. 31

June, 1832.

∠. SECOND CUTTER.

Date.		
10	1 Cutter moored, and Mosquito	22°20′
	1 B.	46.30
	Tang. Alligator	13.14
	Mosquito Is. 16.25 to	23.45
	1 Cutter Tang. Mangrove Pt.	48.50
	Whaler moored; whaler and 1 cr.	88.25
	Knob and whaler	40.20
	Pt. of do. ,, ...	34.25
	Creek Pts. ,, 17.55 to	12.0
	Weighed; to W. 2 . 2½ 3 . . 4 . 5 . 4 . 3 . 2 . to 2 G. 3 . . 4 . . . 4½ 3½ 3 . . to Hawk. 3 . . 4 . 4½ . 4 . 3 2½ . to station 2½ . 3 . . 4 . 2½ . 2 . 1.	
	2 C^2	
	2 G. and J...........	24° 5′
	1 $C.^2$........	50.30
	Heron	56.30
	W^2 moored ..	72.36
	2 G^2 do. ...	119.15
	1 B^2 do. ...	142.30
	W^2 moored, and 1 G^2........	80.54
	2 C^3	
	3 G^2, and 2 G^2........	12.49
	1 B^2........	24.00
	J^2	35.48
	1 C^3........	51. 5
	1 G^3	107.42
	1 $C(^3)$ and 1 G^3 ..	56.37
	W^3 moored, 1 G^3 and W^3	39.18
	2 C^4	
	2 G^3........ 1 C^4	60.13
	Solitary and do...........	42.52
	J^3 ,, ...	26.49
	1 C^4 ,, W^4	67.41
	1 G^4	119. 5
	W^4 ,, 1 G^4	51.24
	2 C^5	
	2 G^4 ,, J^4	45.37
	3 G^4 ,, J^4	25.35
	1 G^4...... ,, ...	9.13
	1 B^3...... ,, ...	2.34
	J^4 ,, 1 C^5	25.20
	1 C^5 ,, 1 G^5	48. 0
	1 G^5 ,, 3 G^5	27.32
	1 G^5 ,, 2 B^3	53.28
	,, ,, W^5	59.50

June, 1832.

FIRST GIG.

Date.		
10	2 B moored; 1 C.	35°00′
	Whaler and 1 C.	31.46
	1 C. and Knob.	5.30
	2 G.	40.3
	Jolly	52.43
	3 Gig	85.40
	Crane	40.6
	Hawk	81.25
	Spire	107.48
	Heron	76.15
	2 Gig ..... 1 $C(^2)$	36.17
	Heron in line.	
	To 2 G 2 . 3 . 4½ 5 . 4 . 3 . 2 . to 1 $C(^2)$ 2 . 3 . 4 . 4½ . 5 . 4½ . 4 . 3 . 3½ . 3 . 2 . 1; to station 1 . 2 . 3 . 2½ . 3 . 2 . 1.	

June, 1832.

FIRST GIG—*continued.*

Date.		
10	1 G^2	
	2 $C(^2)$, and $W(^2)$	50°39′
	Crane and $W(^2)$	27.35
	1 $C(^2)$ .. $W(^2)$	7.55
	$W(^2)$ .. 2 $G(^2)$......	71.30
	1 B^2	110.21
	Jolly^2	147. 0
	2 $G(^2)$........ $J(^2)$........	75.30
	1 G^3	
	2 C^3 and spire..	13.53
	,, 3 $G(^2)$	N. 39.23
	,, 1 $C(^3)$	S. 49.38
	$W(^3)$ moored. ,, 2 $C(^3)$	S. 82.18
	2 B^2 ...... ,, ... do. ..	S. 54.16
	3 G^3 moored ,, ... do. ..	S. 57.55
	1 C^4 moored. ,, ... do. ..	S. 46.57
	J^3 moored .... do. ..	N. 27.15
	Crab and do.	16.30
	1 G^4	
	1 B^3 and J^4 in line, and 2 C^4 .	74.56
	2 C^5................ ,,	63.24
	2 G^4................ ,,	41.41
	3 G^4 .... ,,	27.16
	Eel. .... ,,	12.34
	2 C^4 and solitary............	7.26
	,, W^4	51.26
	1 G^5	
	2 C^5...... 2 G^4	35.55
	3 G^4	59.23
	1 C^5, W^4 in line..	67.29
	W^5 moored, and 2 C^5........	66.56
	2 B^3 .... ,, ...	71.30
	3 G^5........ W^5	63.37

June, 1832.

SECOND GIG.

Date.		
10	1 Gig moored, and 2 B.......	47°23′
	Whaler....	81.28
	3 G. moored, 3 G and 1 G. ..	81.58
	Spire, 1 G.	89.55
	Hawk ,,	102.18
	2 C^2 moored ,,	110.23
	1 B shifted ,,	124.11
	1 C^2 moored ,,	127.30
	Heron ,,	128.20
	Weighed: To 1 C. 2 . 2 3 . 4 4½ 5 . 4½.	
	Heron and Hawk .... 90°22′	
	Hawk and crane...... 89.40	
	to 2 C^2 4 . 3½ 3 2 . 1 . to 1 G^2 1 . 2 . 3 2½ 3 2 1.	
	To station 2 . 3 4½ 5 . 4 . 3 2 1 moored W^2 N. 1 G. E.N.E.	
	2 G^2	
	1 G^2 .... W^2	52°14′
	Spire	18.40
	2 $C(^2)$...........	23.28
	3 G^2 and 1 G^2	14.33
	2 $C(^3)$ .. ,, ...	18.42
	1 $C(^3)$ .. ,, ...	33.15
	$J(^2)$ .... ,, ...	54.40
	1 $B(^2)$ .. ,, ...	65.17

June, 1832. SECOND GIG—*continued.*

2 G(3)

10 Took up position on inner side of Solitary. Tangents on 3 G^3 and 2 C(4).

Date			
	1 C^4	2 C^4	58° 13′
	3 G^3	1 C^4	21. 32

2 G^4

Date			
	3 G^4	1 G^4	14. 8
		1 B^3	41. 45
		J^4	51. 28
	J^4	1 C^5	41. 57
		1 G^5	59. 32
		3 G^5	64. 37
		2 B^3	81. 25
		W^5	84. 10
		2 C^5	84. 54

2 G(5)

Date			
	3 G^5	W^5	18. 35
		2 B^3	19. 30
		Tang. bend	41. 5
		J^5	50. 39

June, 1832. THIRD GIG.

Date			
10	1 G moored, and	2 B.	23° 55′
		Whaler	40. 44
		2 G	52. 25
		2 Gig and Crane	7. 3
		Jolly	62. 15
		Hawk	111. 30

3 G^2

2 G^2 W., J^2 S.W., 1 B^2 between.

Date			
	2 G^2	J^2	48° 48′
		1 B^2, J(2)	26. 50
	J^2	1 C^3	68. 50
		1 G(3)	78. 43
		W(3)	95. 6
		2 C(3)	111. 30
		Crab	113. 50

3 G^3

2 B^2 moored, spire in line.

Date				
	1 C(3), and	1 G^3	S.	22. 52
		W^3	S.	39. 14
	2 B^2 & spire, and	1 C^3		52. 25
	J(3) moored, and	1 C^3		62. 45
	2 G(3) .... and	J^3		19. 25
	Solitary	,,		30. 10
	1 C(4) and	J^3		59. 20
	,,	E Tang. Solitary Id.		26. 15
	,,	Sand		26. 45
	,,	West		39. 55

3 G^4

Date			
	W^4	1 G^4	50. 48
	1 G^4	1 B^3	69. 4
		J^4	81. 10
		1 C^5	102. 30
		1 G^5	105. 55
		2 B^3	118. 21

June, 1832. THIRD GIG—*continued.*

Date			
10	1 G^4	W^5	120° 25′
		2 C^5	127. 17
	1 G^5	2 G^4	45. 5

3 G^5

Date			
	W^5	2 B^3	3. 17
		2 C^5	29. 57
		1 G^5	51. 35
		J^5	95. 7
	J^5	2 G^5	48. 31

June, 1832. JOLLY.

Date			
10	3 G moored, and	1 G	32. 33
		Crane	46. 30
	Hawk .... and	3 G	17. 44
	Spire	do.	42. 14
	2 C(2)	,,	64. 10
	1 G(2)	,,	77. 45
	1 C(2)	,,	80. 5
	Heron	,,	82. 50

J(2)

J(2) moored, 1 B. N.W.; 2 G. N.W. by N.; 1 G. N.

Date			
	1 G(2), and	2 G^2	49. 50
	3 G(2)	1 G^2	41. 25
		W(2)	57. 00
		2 G(2)	91. 15
		1 B^2	102. 11
		Spire	14. 30
		Crane	45. 26
	2 C(3) and	3 G^2	32. 42
	Crab	,,	36. 15

J(3)

Date				
	1 G^3, and	W(3)	S.	22. 00
		3 G(3)	S.	63. 43
		2 B(2)	S.	62. 8
	3 G^3, and	1 C(4)	S.	50. 04
		W(4) moored	S.	60. 18
		1 G(4) moored	S.	78. 0
		2 C(4) moored	N.	93. 42
		Eel.		95. 24
		Solitary		115. 02
	1 C^4 and	tang. sand do.		50. 55
		Trees		56. 35

J(4)

Date			
	2 B^3	3 G^4	128. 56
	3 G^4	W^4	27. 45
		1 G^4	51. 22
	2 G^4	3 G^4	58. 42
	2 C^5	2 G^4	49. 29
	W^5	2 C^5	18. 14

J^5

Date			
	3 G^5	W^5	49 58
	2 G^5	3 G^5	80. 50

To survey an island from the sea, the same process as that described for plate I. is to be observed.

In performing this operation, work directly to windward of the island, and start from such a position that you may carry a free wind on three sides. By this method the errors of leeway are obviated, and positive courses *steered.* Thus, for instance, as in the diagram, plate IX., let the wind be N. and the island to be surveyed under canvas. The rate of sailing should not exceed five knots—three is more convenient.

It is also *advisable* to be nearly on the meridian of some conspicuous points at 9 A.M. and 3 P.M., or at the most convenient times for determining the longitude by chronometer; and on the parallel at noon. At all events, bear in mind, that the island must not shut you out from using the horizon for the sun at noon, in whichever hemisphere you may be, as both latitude and longitude would then be involved in doubt.

If surveying with two vessels, it is advisable to run from the wind's eye of the centre of the island, so as to be east and west at noon ; and to measure base by sound, just before losing sight of each other on the N., and again, when in sight, S. (as *a a*, *b b*, plate IX.) The diamond form, as dotted, will then be preferable, as neither vessel will stand the chance of being becalmed under the lee.

The method of surveying a coast under canvas, or " a running survey," differs but little from that we have just been treating on. It may be very shortly explained by the characters on plate VI. Thus, the vessel arrives in sight of the land objects at $\triangle^2$. Here she anchors, and if unable to land, or get nearer in shore, determines her position astronomically by the sea horizon, and obtains true bearings of all objects in sight. She then starts, with perhaps two patent logs over ; one on each quarter, so that the hauling in one may not vitiate the long base of the day. To perform this operation neatly, and not be in doubt as to the course from the point of starting, from drift, making sail, &c., it will be advisable to despatch a boat, say to R^2, and measure base by sound to her. Her position being astronomically determined in bearing, the course and distance to her will then become a first base, and if boats could have been spared, another, or the barges, could have taken up W^2, 2 $B.^2$, &c. Before sunset it is requisite to anchor, and determine the position of the ship before starting on a new base. If the country be mountainous, and the peaks

well defined, the position of the ship is frequently determined by known positions, and thus the continuation of the survey by their means may be almost trigonometrically maintained, independent of any marine bases.

The following example of a coasting survey, being the two first bases of a day's work, will serve for practice. One line of soundings by the ship would be obtained, and perhaps others by the tenders, which, after objects were fixed, would be enabled to work traverses.

On ♂ 28 V/[33] at 4h. 37m. 31s. A.M. observed the land bearing S. 88°. E. (estimated true) took the following observations, and put pat. log. over. Object, Pinnacle Peak.

28 V/33 4h. 37m. 31s.	8647	$\underline{\odot}$ 5° 17′ 0″	$-\!\odot\!-$ 25° 14′ 30″.
Lat. 37° 29′ 20 N.	Long 8° 40′ E.		Decl. corrected 21° 25′ 22″.

The resulting true bearing is, S. 88° 3′ 30″ E.

The following angles were taken at the same time.

Pinnacle peak and Flemish cap	. . .	31° 56′ 30″
Asses' ears	. . .	50 56 30
Misty mount	. . .	67 58

Course steered N. 18° E., variation 18° westerly, or course north true.

At 5h. 20m. By second astronomical bearing, Pinnacle Peak bore S. 40° E., and the run by patent log was found to be 5 miles. The following angles were then taken—

Pinnacle peak and Flemish cap	. . .	5° 5′	
Asses' ears	. . .	11 15	
Misty mount	. . .	28 3	
Crane peak	. . .	63 20	*New.*
Ridge crest	. . .	114 10	*New.*
North extreme point	.	130 5	

Standing on same course.

At 6h. 10m. distance by patent log 11′, 2. True bearing of Pinnacle Peak S. 20° 48′ E. The following angles were then taken.

Misty mount and Pinnacle peak	. . .	5° 45′
Asses' ears and ditto	. . .	3 44
(Flemish cap shut in.)		
Pinnacle peak and Crane peak	. . .	1 8
Ridge crest	. . .	21 37
N. extreme (Bluff edge)	. .	47 12

This, then, is an example of a running survey. The projection is simple, and will afford practice. With the data furnished in the first instance, work out the astronomical bearing, recollecting that the character attached to the apparent distance designates that the sun was taken to an object which touched its southern limb, and therefore the horizontal angle is additive to the true bearing, the time being A.M. and the observer in north latitude.

Draw the meridian, (which in this case is the true course,) and allowing room for the protractor, mark the ship's position at the lower part of the meridian. From that position lay off the true bearing of the Pinnacle Peak S. $88^{0}\ 3'\ 30''$ E. Reduce the angles to true bearings, thus, Pinnacle Peak S. $88^{0}\ 3'\ 30''$ E. $+ 31^{0}\ 56'\ 30'' = 120^{0}$ from the south, and so on with the others. Without moving the protractor from the paper, lay off these angles from the *south.*

The position at which the next set of angles and true bearing were taken is five miles; assuming the scale at one inch to a mile, lay off five inches for the distance run, and place the protractor on this point, the zero north and south. Lay off in a similar manner the second true bearing of the Pinnacle Peak and other angles, and mark the positions where the intersections occur.

Treat the third distance the same, bearing in mind, that as the patent log is not reset, the distance on that base will be $11',2-5=6,2$. At this third position then, the angles, if the ship had been fairly steered, and the observations accurately taken, should again cut the former objects. Such then, with more numerous objects, and repeated, perhaps, on a length of fifty miles, would afford an idea of a running survey of a coast which would not admit of convenient anchorage for triangulation, or which is too "steep to," to admit much greater nicety. The positions at the extremities being astronomically determined, and frequently corrected by observations taken on shore, are readily transferred to the chart by "squaring in" between the astronomically determined positions.

The principal objects once determined, boats or tenders may fill in the detail and soundings.

Sufficient, it is hoped, has been adduced to show how much can be performed afloat by the sextant. Its value is equally important in conducting surveys of ports, if the objects be kept as near the sea level as possible, but we shall proceed to land operations.

We now arrive at that point of surveying in which the theodolite is chiefly employed, and as one case may be made to combine all that

may be called for, we will select an instance that will embrace not only risk, but also secrecy, and the duty of an engineer. All that may *reasonably* be looked for from the marine surveyor will first be treated on.

We will therefore assume that in plate VIII. the northern half is in our possession, and that it is requisite to produce a complete plan of the other, as far as the objects are above water; bearing in mind that the enemy will not neglect dropping shot or shell the instant the officer or a party is distinguished.

Harbour Survey.

As the base must, in this case, be measured, (either before or after,) we will first treat on the methods of performing this operation, and show how verifications may be obtained during the progress of the survey. Of course such operations must be conducted out of sight, and it may occur that the ground will be uneven.

On the level.—If a level can be obtained, we select that line which will best adapt itself to one of the stations, or probably, make one extremity a principal. The measurement may be made by rods or chains,* but in using rods, it is preferable not to permit them to touch, but rather measure their distances between zero, and note thus: 1st rod + 1,7, 2nd rod + 1,1, &c. By this method errors are obviated in two ways: first, being free from jar, and, secondly, there is little chance of mistaking the *number* of rods, as the corrections are themselves a duplicate check.

In carrying forward a straight line, boarding-pikes are convenient, and a few should have the boat's flags attached. Point the telescope of the theodolite in the opposite direction of the intended base, and cause the assistant to place one pike about twenty feet in that line. Let him now proceed in the intended direction, and using a heavy stone and fishing-line for his plumb-line, with two spare boarding-pikes as sheers for the latter, cause the line to cut the telescope (set erect) and the rear pole: this should be true. In fixing this first pike into the ground he should take pains to make it coincide

* Never take the length of a chain into the data until it has been fairly measured on deck, and been subjected to a moderate strain. I have found them both *longer* and *shorter* by six to eight inches than they should have been. Before trial, let them be measured on the ground to two points of verification, and *remeasured* after the operation. New chains which have their connexion by circular rings must evidently yield to moderate strain; in fact, their whole principle of construction makes it evident that some alteration should take place. The rings should be strained into ovals.

with his plumb-line. At every 200 feet a flag should be placed. He will adopt the same plan in his succeeding marks. The *exact* distances between these flag-pikes should be measured. If the whole extent can be completed, good. But let us suppose that circumstances render it imprudent, or that the ground will not hold out above 800 feet on a level. Let the assistant or principal go to the centre staff, and with a pocket sextant (or any rectangular object, book, &c.) notice a spot on either side at right angles to the base. Proceed to that position, which may be guided by the theodolite at 60°, and place a staff, as at *c*, keeping the two staves in line; then place *d*.—(*Vide* Plate IX. fig. 2.)

Point the theodolite to 120°, and let the poles *e*, *f*, be placed; the first by keeping on the 120° line, (*a d*, or *b c*, in line,) and by pocket sextant 60° to *c* or *d*; the second by bringing *b c*, or *a d*, in line, $\angle$ 60° to *c* or *d*, and the centre and last placed in line as *d a f* in line; *e* centre and *f*, and *c a*=60°. It must be evident, that if nicety be observed in measuring the angles at *a*, *b*, *c*, and *d* only, that *e*, *f*, must be as well known as *a*, *b*, for every triangle is equilateral. Thus, 2100 feet may be completed. If this figure be followed out to the greatest nicety, and the 200-mark flags be attached with heavy stones suspended, to fine lines from triangles, (which I have tried repeatedly,) greater nicety is attained; (and I have frequently taken each triangle separately from *c* and *d*, as denoted by the dotted lines;) 800 feet thus measured would satisfy me better than the whole direct measurement, provided *first-rate* instruments are employed.

It sometimes occurs that the ground is too uneven to admit of any degree of nicety: recourse may be had to suspended rods. I have not, however, measured any distinct base on this plan, having only lately completed the set of rods. I shall, however, proceed to show the principle, and point out how a base may thus be conducted over rugged rocks, water, &c. I propose to make use of five cases of rods. The case complete contains twelve rods of twelve feet. It should be twelve feet six inches long, furnished with a brass plate at one *end*, and on the opposite terminating bottom, a plate cut with a slit, and a hinged bar to fall across into a notch of metal parallel to the slit—both being capable of adjustment—to twelve feet. The rods are shod with brass, and at one end furnished with a screw with capstan head, for the purpose of elongating or shortening. One rod is to be measured by the standard; it is then put into the box with the others, and

the whole vibrated to make them stand on their metal ends. By dropping the hinged bar they can all be brought to the same guage by their screws, and we have thus 144 feet of well-measured rod.

Let one or two coils of well stretched rope, or light boat's chain, be stretched between the points to be measured, and supported by sheers (of pikes) at every forty feet; suspend these rods on the plan of a suspension bridge, [I have large curtain rings through which they *traverse*,] and bring them as nearly level as can be done by a small spirit level. When all are suspended, erect a pike at one end, and with a piece of wood tap gently at the other until they are all *home*. Suspend a plumb-line *independent* of the rope, and continue the measurement, which, if five cases are at hand, will give one complete distance of 720 feet. Each case contains twelve rods of one inch diameter, which therefore occupy a space of three inches by four internally, by twelve feet six inches long; or externally, twelve feet eight inches, by five inches, by six inches.

Lastly, it may not be practicable to gain any other base than by the buildings, walls, &c. These may easily be measured, and particularly if the upper windows in any particular street be observed, endeavour to obtain access—drop a plumb-line with a considerable weight into a bucket of water, and measure the distance in the street; the angles may be obtained by theodolite to two stations from the extremities (the windows;) also by sextant directly. Where the surveyor is intent on his purpose but few *difficulties* are known to him; the word impossible cannot (or ought not to) be found in his vocabulary. Let us, then, imagine all these have failed, from *danger* of shot and shell. Many barefaced things can be executed by night as well as by day. Let preparations be made for *temporary* dark-lanthorns, and conduct the operations with them, taking the precaution to keep each light in its bucket until required, and then its illuminated side only towards the observers; the person attending it interposed with a pea jacket.* The light to be held so that the plumb-line, if adopted, may be seen between the light and observer.

Excepting cases where latitude and longitude may be eventually or directly involved, the error of ten or fifteen feet in a mile is not of the slightest importance in the common surveys of places uninhabited, or little visited. In such cases, a patent-wove line of 500 feet

* Upon this principle, by semi-illuminating the marks used in the survey, the government despatches in the "London Merchant Steamer" went over a heavy bar at Oporto about midnight, unperceived.

will be found a very convenient assistant, to be verified on smaller bases measured by chain. The wove-line alluded to, is composed of strands of twine wove circularly, and the strands therefore always straight in the line of strain, and when once stretched, wetted, and allowed to dry with a moderate strain, will not contract or expand above one foot in 500 by any force, unless it be immoderate. A measurement of 1700 feet by line and chain repeated three times, differed, 1st = 9 inches, 2nd = 11 inches, 3rd = 7 inches. This is near enough for the common purposes of surveying, particularly when we take into consideration that bases by sound are subject to still greater error.

There is yet another method, by micrometers, or by the known height of some steeple or lofty building. The principle by micrometer hardly requires explanation. By simple trigonometrical means it can be ascertained at what distance forty or fifty feet (or less) will subtend one minute. As the micrometer is read to seconds, it is merely necessary to view a measured pole or distance by it, and the base may be computed as on the larger scale by greater measurements.

Before taking leave of this subject, we may observe that the length of the ship and spars may very conveniently be adapted, (better than the altitude of the masts,) if two or three observers are used; and under way, nearing an enemy's vessel, approaching their works, &c., this method may be frequently found of *value*. Let a hole be bored in each quarter to support a stancheon. Let the true distances between this and the bowsprit staff, the jib-boom end, the flying jib-boom end, and the length of the driver-boom end, beyond the stancheon, be accurately determined. From the weather-quarter an observer can be seen a-head, if the foresail be up. Let two observers at the extremities of any of these points, measure the angle between the object required and a white stick or chalk mark, on their respective hats, and the distance will be found, more or less in error as the angles are acute, or the base inclined.*—(*Vide* Diagram Fig. 1, p. IX.)

The first consideration with the surveyor should be the selection of stations; much time is saved by devoting a day *solely* to this subject and directing the raising of marks, particularly if he be so circumstanced as to be compelled to keep out of "harm's way." Two or three principal *secure* stations should be fixed on for determining the main triangles by his best theodolite, independent of his observa-

* In measuring by this method the extremity opposite the observer on board should be marked by a pike with a lead suspended clear of the water, so that its point (which should be a foot above the object) may be used as the reflected object.

tory, which should be sheltered, and near the sea, in sight, if possible, of the principal heights.

It should afford the means of watching the tides, to which duty one person should be stationed. If magnetic experiments be carried on, both these duties may be combined. In erecting and making marks, the lime-bag will be found of importance; and a very simple method of marking a spot is to wet the place, and *cast* powdered lime *at it*. It is more convenient, economical, and the mark lasts longer. Wherever theodolite stations are to be fixed, a staff four feet six inches, with a roll of paper tied round by a dark line or rope-yarn, should be driven into the ground to the usual theodolite height, so that in taking elevations the original line of position from whence angles or depressions were *taken* may be had. If a post be used, let it have such a mark.

Wherever a station is to be fixed, let it be *available*, and let the theodolite occupy its position, plumbing the centre or hole in which the mark was placed. Do not involve "the calculation of reduction to the position;" this may do well enough where one or two angles are involved, but a little forethought will prevent the necessity of thus throwing a whole round, perhaps exceeding a hundred objects, into doubt; rather let a staff be placed some few yards from the object, (even if it be a flag-staff,) and make it a station, as the one angle can conveniently be calculated for the position of the staff, although its measured distance is sufficiently near for any purpose connected with marine surveying. There is also another great objection to placing the instrument beside the staff, even if it be furnished with a diagonal eye-piece, which takes away half the objection. The staff must shut out a great portion of the horizon, equal to the arc of which the diameter of the staff would be the chord.

Or, in plain distances, taking the staff at twelve inches diameter, it may be assumed from the rarefaction of the ascending current of air on dark-coloured spars, exposed to the sun, that at three feet from its centre the angle will be about $18\frac{1}{2}^{\circ}$, or faulty from the cause above stated . . . . 20°

At two feet about 29°, or 32

At one foot about 60°, or 65

Exposed to a tropical sun it has been found to exceed this. Assuming the instrument to be a five-inch theodolite; we have six inches for the spar, and five inches for the telescope from centre, if provided with a diagonal eye-piece; otherwise, six spar, six head, and five telescope, would be the nearest position that the instrument could be placed in,

unless the opposite 60° to the staff were void of objects, as the sea horizon, &c. For the common purposes of marine surveying, where no intricate or important data are involved, such a position may be taken, provided the staff is fixed from two good stations in the main triangulation, and will not vitiate the computation of the survey.

Stations should never be multiplied if it can be avoided, excepting as auxiliary, for the completion of the bays, tangents used in sailing directions, &c. The true bearings of all points visible from the observatory will of course be determined from it. If the observatory be not fixed, recourse must be had to the theodolite, and the astronomical bearing obtained by it, which is one of the first requisites in commencing the protraction of the angles.

The stations being fixed, and the angles obtained from the three principal, we will now proceed to paper. On a piece of cartridge lay off roughly the true bearing and distance, (either estimated or measured,) and determine on the most advisable scale, (after forming one or two great triangles,) so as to include the whole work on the same sheet. This will save your sheet from being unnecessarily cut up by rubbing out lines, &c., and guide you in fixing your main positions, so that they may come clearly on the fair paper, or not interfere with a joining of sheets. Nothing betrays want of forethought more than the meridian being out of the parallels to the sides of the paper, the work hedged up into one corner, or pieces pasted on when plenty of blank paper remains on the original sheet, not perhaps even devoted to soundings.

The principal, then, is at his work. His assistants with light theodolites or pocket sextants, are detached to minor stations to obtain the detail, should the principal be *unable* to attend to it. But his duty includes every part of the operations, and as his character is staked by his signature to the work, he must be confident in those he employs upon such *(his)* duty.

At the springs and neaps a person should be detached to the entrance, or beyond the influence of freshes, to determine the rise and fall.

It treating of the *detail*, some explanation perhaps is necessary. The principal will probably give his instructions in writing. There are many reasons for this, and I cannot forbear to point out the variety of feelings which may be unduly excited and misconstrued, and to show how important it is that time should not be lost in unnecessary explanation. It must be evident to the meanest comprehension that the mind of the principal having a body of men of various shades of

character and pretension to direct, devoted to the pursuit of his duty, and having enough, one would imagine, in contemplating his own plans, must be sensibly alive to questions at the moment perhaps all should be at their posts. To avoid all such, it is infinitely better to devote time to the framing of distinct orders, on which no comment is to be made, and which it is well known must be completed, or others more competent will be employed. It is to be confessed that it is a very grating duty to have to select another of *(thus acknowledged)* superior ability, or be compelled to do the inferior work one's self. But there is but one line. It is demanded by the service—the duty must be done. To proceed, however, with the orders; form a triangle on the face of the order which is to include the stations, and let the directions require the party, to complete the coastline and topography within its limits, noting such points, stations, tangents, or rounds of angles, as may be wished. The wording of such orders, must be suited to the comprehension of the party selected. In the event of the person so employed being of known ability, (that is, to the principal,) the *form* of an *order* is only requisite, that no invidious distinction may be drawn; but it should not be *omitted.* It costs little, and the tone and conversation of the principal assure him that he is not undervalued.

Although it may be imagined that the daily duties of the surveyor are arduous enough, yet his interest appears to receive fresh impetus as day closes and the stars begin to show; and he will probably be found watching their motions until dawn warns him, that some little repose is necessary to perform properly the duties of the ensuing day. His chronometers may not perhaps demand daily observations for their rate, as he probably rests on his transit, or is satisfied with five day, or weekly intervals; yet the necessary observations for determining to the greatest nicety the latitude and longitude of his position, cannot be omitted.

The first station we commence with will be Flat Island, from which the astronomical bearing of the observatory at black cross (being a mark perpendicular to the centre of the instrument) is to be determined, as follows:

The observations being taken by a transit* theodolite graduated to 10″, the entire set of observations as practised (before and after the round of angles) has been introduced.

* This is a private instrument, and is now fitted to reverse on its axis before reversing in azimuth, by which four sets are obtained free from the errors incident to motion in azimuth.

First, then, at Flat Island zero Black Cross station:—

	Times.	Z. D. do. Ω Left.	Right.	⊙ Centre.	
	h. m. s.				
	11 0 38	61° 40′ 30″	40′ 40″	247° 34′ 30″	67° 34′ 30″
	2 31	35 10	35 30	48 10	48 20
	3 14	30 30	30 40	58 30	58 20
	7 23	106 10	106 50	141 10	141 10
	10 2 27.7	61 35 23.3	35 36.7	247 47 3.3	67 47 3.3
		36.7			
		60.0			
		61 35 30.0			
	Reversed.				
	h. m. s.				
	10 4 36	61° 23′ 10″	23′ 30″	248° 17′ 50″	68° 17′ 40″
	5 19	19 10	19 0	28 30	28 40
	6 2	14 30	14 40	40 0	40 0
	15 57	56 50	57 10	86 20	86 20
	10 5 19	61 18 56.6	19 3.3	248 28 47.6	68 28 46.6
	2 27.7	19 3.3	. . .	247 47 3.3	
Mean	10 3 53.5	37 59.9	. . .	15 49.9	
	Mean reversed	61 18 59.9	. . .	248 7 54.9	
	Mean direct	35 30	. . .	111 52 5.1	⊙ ∠ dist. from Zero.
		54 29.9			
	Mean Z. dist.	61 27 14.95		Magnetic.	
	Ref.	1 43.59			
				256° 57′ 00″	
		61 28 58.54			
	Semi-di.	16 8.00		76 57 00	
		61 12 50.54			
	Parallax.	7.62			
	T. Z. D.	61 12 42.92			
	T. alt.	28 47 17.08			

Lat.	41° 8′ 54″	Sec. 0.123200	Decl. 13° 53′ 23″	Var. 19′ 32″
Alt.	28 47 17	Sec. 0.057290	1 34 cor.	
Diff.	12 21 37		Corr. Decl. 13 51 49	
P. D.	103 51 49			
Sum	116 13 26			
Diff.	91 30 12			
½ Sum	58 6 43	Sine 9.928950		
½ Diff.	45 45 6	Sine 9.855108		
		19.964548		

73° 44′ 29″ =	Sine 9.982274	True bearing zero	S. 79° 21′ 3″ W.
N. 147 28 58 E.		True N.	100 38 57
+ 111 52 5	⊙∠ distance from zero.	Mag.	76 57 0
259 21 3		Var.	23 41 57 W.
180 0 0			
S. 79 21 3 W. =	true bearing of zero.		

The result from Black Cross station we will take for granted to be the same within a few *seconds*, which cannot be *protracted.* It is to be presumed that in the course of the survey numerous determinations of true bearings will be obtained, and at the main station, (Black Cross,) or where the observatory is supposed to be, the *true* meridian will be determined by the *transit* instrument.

The stations have been numbered, and therefore it will be understood that they are protracted in numerical order. In completing this plan we are assuming the whole south side hostile, and that a complete survey is to be made of that side, as far as materials above water are involved. It is proposed to divide the plan into parts, and finish one part only of the *particular* objects, thus showing at sight the different stages of the work of such a survey, and affording a fair sample of the common duties of a surveyor in harbour.

The main triangles will first be computed from the base measured, and artificially extended, as before noticed.

Inaccessible objects will be fixed, and their exterior features outlined by tangents, (or lines which touch their extremities.) Batteries

and fortifications generally will be outlined, as in the defences of the town.

The force, elevation, range, &c. of batteries will be defined, (as range from Blockade battery.)

Conspicuous houses will be fixed, either to define the coastline or assist lines of soundings (to be hereafter taken.) All dangers visible at low-water springs will be fixed.

Every surveying officer is supposed to carry with him a sketch-book, and at every station he visits, fill in by eye the immediate adjacent coastline. (I have found it convenient, after the great angles are protracted, to take a rough copy into the book, and work by it. A horn protractor is useful in this part of the work.) In noting angles of batteries, a slight sketch on the angle book is convenient. The number of embrasures should be noted, and where the principal is alive to the motions of an enemy, he ought to travel with his pocket sextant and telescope, and by taking angles, as if he was sounding, determine the extent to which every gun in the enemy's lines can be brought to bear. This is to be done by determining the angles of the embrasures. A battery gun can be trained 5^0 beyond the angle. Thus, let us assume that the angles of the embrasures are 60^0, and that the internal aperture is two feet six inches. The long 24 Pr. where it enters the embrasure is about one foot five inches, (or less,) and greatest muzzle diameter the same. If the muzzle and the side of the gun touched the embrasure, that would be a parallel to the bore, but if we take the diagonal of the 24 Pr. (at the point in question,) at the angle of the embrasure, say 60^0, we have a measurement of about $19\frac{1}{2}$ inches, $30-19\frac{1}{2}=10\frac{1}{2}$ inches, as the base of a triangle with the outer extremes of the embrasure. However, excepting in cases of necessity, guns are seldom discharged to injure the works, therefore the angles of the embrasure $+\ 5^0$, may be safely assumed. Those accustomed to the report of guns can pretty well estimate their calibre; but the shot in such cases as the present are too frequently sent with the information. These should be collected and *guaged.* Calculation has not unfrequently been made on the supplies "*to be captured.*" The guns have been captured, spiked, or destroyed, and the shot proved too large for other ordnance.

Measurement of Base.

A convenient spot of a quarter of a mile having been cleared in the flat ground near the observatory, 1518,9 feet were measured, the centre line from the observatory having been calculated to cut its centre at right angles, and measures taken to elongate it, (as in diagram, plate IX.;) a base of 4418,99 feet from Black Cross to *f*, or N.E. flag, was thus obtained, as in the computation following the angles. The angles at Black Cross and Slaughter Hill will be found in their formulæ. Those taken at the flags were as follows:—(The flags were on plumb lines.)

At *d*, Black Cross Zero.	° ′ ″
Flag on Slaughter Hill	49. 6 .24
a	90. 0 .0
c	180. 0 .0
f	229. 6 .24
b	270. 0 .0

At *c*. lines of Flags and Observatory Cross Zero.	° ′
a and Slaughter	33. 0
f	270. 0
b	330. 0

At *a*. Zero *b*, and centre flag, in line.	
d	60. 0. 0
Black Cross	75. 0. 0
Slaughter	120. 0. 0
c	300. 0. 0
f	330. 000

At *b*. Zero, Centre flag and *a* in line.	° ′ ″
c	60. 0. 0
f	120. 0. 0
Black Cross	285. 0. 0
d	300. 0. 0
Slaughter	330. 0. 0

At *f*, Zero Black Cross.	° ′ ″
b d in line	9. 52. 45
Centre & Slaugh.	28. 59. 10
a	39. 52. 45
c	69. 52. 45
Flat Island	273. 49. 45
Mt. Misery	174. 7. 45

The main external angles being complete, the smaller will be computed.

In protracting, some have advised letters, numbers, &c. Where above 100 objects are involved this is inconvenient. I have generally adopted symbols and letters; but the letters seldom exceed five or six, and follow the angles of a station. Every one can form his own sym-

bols; the first sixteen angles* from Slaughter Hill, I perceive, can be included by such.

The first station, then, will be Flat Island, determined on the base from Black Cross to N.E. flag: thence on that base, will follow, Mount Misery, Grassy Point, and Prospect Hill; Slaughter Hill, already determined in the computation of the base, must now be brought into the main triangles. Thus far all has proceeded clearly, and from these positions the tangents and points in the bay have been completed, and the works of the town outlined. Before we can satisfactorily advance, it is requisite to fix the steeple of St. Juan's, (no determined second position being available from Green Mount or Fort William.) Now, as this position subtends angles on two bases respectively, (as will be seen at Nos. 8 and 11 in table,) of 52° and 59° nearly, there can be no doubt of its accuracy; and as the angle at Green Mount subtends 86° nearly, between the steeple and its zero, (Mount Misery,) there can be no hesitation in securing the station by laying off the resulting angle from the steeple; or, having computed the distance, lay it off by beam-compass or graduated scale, as it is preferable to avoid protracting long lines, which cannot be satisfactorily produced beyond ten to twelve inches, whereas the distance may be measured to hundredths of the inch. The same observations apply at Fort William, and, as will appear more evident, at Danger Island, which is principally fixed from the Summer House Battery. These points have *purposely* been introduced to show that it is not necessary to have access to an opposite side of a river, if objects can be had to carry on the survey on one of its banks. Although Green Mount station was secured from St. Juan's steeple, the two triangles (including Fort William, the *truck* being seen from Green Mount,) are proved by computing the angles from the legs, in the event of the flag-staff being out of the perpendicular, which would have been very probable if the wind had been moderately strong. The stations being determined, and the land confined within the tangents, the topography should be lightly *dotted* out. Where hills show abrupt crowns, as in Barren Mount, they should be outlined by tangents. This applies to ravines, streams, knolls, &c. which are also laid down by eye in the sketches taken at the different stations.

The following are the angles:—

* Refer to plate VI. with the angles of Slaughter Hill, and it will be found that the twenty-five symbols will embrace all that can be wanted; thus S H. and the *flag* designates flag of Summer-house battery; the second, the abbreviation of Peninsula with the upright line, denotes brow; the three points, *cliff*, &c. Of course the symbols of familiar objects are preferable, and each should use his own..

Date.	No. 1.—October, 1832. STATION ON FLAT ISLAND.				Z. D.
30	Zero Black Cross.			Magnetic 76° 57′ 0″	
	Times.	⊙ Z. D.		Reading.	
	h. m. s.				
	10. 1. 38	61° 40′ 30″	40° 40′	247° 34′ 30″	67° 34′ 30″
	2. 31	35. 10	35. 30	48. 10	48. 20
	3. 14	30. 30	30. 40	58. 30	58. 20
	Instrument reversed.				
	10. 4. 36	61. 23. 10	23. 30	248. 17. 50	68. 17. 40
	5. 19	19. 10	19. 00	28. 30	28. 40
	6. 2	14. 30	14. 40	40. 0	40. 0
	Zero and levels perfect.				
				° ′	Z. D.
	South base staff			11. 45	87° 58′ 20″ d.*
	Slaughter Hill			11. 50	58. 10 58. 0 r.†
	East Flag, main base			23. 0	58. 0
	West 21. 00. Centre			21. 53	
	Cricket Point			15. 0	
	Red Point mark			27. 15	
	N. base flag 31. 30 N.E. = *f*			35. 57	
	Crown of Barren Mount			38. 55 to 47. 0	
	Tangent Black Bluff			40. 30	
	Mark			45. 0	
	Rocks off, 35. 00 Do. *awash*			32. 0	Z. D.
	Mount Misery			56. 0	84. 20. 20 d. 21. 00 20. 40 r. 20. 50
	N. Steeple, Town			233. 0	
	Houses, tangent			202. 0	
	High Steeple			278. 0	
	Mark on Skiff Bluff			343. 30	Z. D.
	St. Juan's Steeple (door in line)			344. 24	88. 20. 10 d. 20. 20 20. 40 r. 20. 30
	Tangent Skiff Bluff			347. 0	
	Outer tangent, Cross Peninsula			349. 0	
	N.E. rocks			353. 0	
	Staff near do.			352. 0	
	Works of Town.				
				° ′	
	Tangent North ∠ lines			197. 30	
	Battery ∠ in line steeple			278. 0	
	Angles of two bastions in one			345. 0	
	Flag-staff and angles do.			341. 0	
	Intermediate battery, near			314. 46	
				319. 15	
	distant			326. 45	
	Zero, correct			Magnetic 76. 57	

* d. = direct. † r. = reversed.

No. 2.—October, 1832.
BLACK CROSS STATION.

Date.			
30	Mem. Transit line agrees with bearing from the station on Flat Island.		
	Zero Flat Island. Mag. 256° 55′		
	Tangents of Island 359° to	2 50	
	Tangent houses........	1 15	
	North steeple	7 20	
	Skiff Bluff tangent.....	9. 45	
	Mark of do...........	10. 10	
	S. tang. in line prospect.		Z. D.
	Prospect-hill.........	10. 40	88° 55′10″ d. 55. 30 55. 10 r. 55. 40
	High steeple.........	11. 40	
	Gap of Grassy Pt. 33° 15′ to	35. 15	
	Grassy station	39. 15	
	S. tangent bluff.......	41. 36	
	Object on near Pt. in line Grassy	39. 15	
	East base flag 297°; west 267°; centre 282°; three flags in line.		
			Z. D.
	N.E. flag............	302° 7′ 15″	81. 46. 50 d. 46. 50 47. 50 r. 47. 30
	Slaughter-hill	237. 0	
	Crown of Barren Mt. 290° to............	294. 30	
			Z. D.
	Mount Misery	300. 0	84. 8. 40 d. 8. 50 9. 00 r. 8. 40
	Red Pt..............	306. 0	
	Cricket	308. 15	
	Snipe...............	318. 30	
	Black bluff tangent ...	335. 00	
	Mark	337. 5	
	Tangent...	343. 30	
	Lines.		
	N.W. bastion	1. 15	
	2nd bastion..........	5. 00	
	West do.............	5. 3	
	Flag-staff............	6. 28	
	S.W. angle of do......	7. 00	
	S. intermediate flank 16° 40 to	18. 40	
	S. angle of works	22. 15	
	Zero correct .... Mag.	256. 55	

No. 3.—October, 1832.
MOUNT MISERY.

Date.		
30	Zero, Black Cross. Mag.	136° 58′ 20″
	N.E. base flag........	356. 15. 0
	E. 2° 18′; S. 5° 10′; W.	19. 55. 0
	Centre	11. 58. 0

No. 3.—October, 1832.
MOUNT MISERY—*continued.*

Date.			
30	Extremes of St. Juan's town 8° 20′ to	12° 10′	
	St. Juan's steeple and door .	11. 15	
	Slaughter-hill	18. 4	
	Crown of Barren Mt.......	23. 10	
	to	34. 00	
	Ravine	35. 50	
	Paps .... 1.........	40. 30	Z. dist.
	2........	49. 00	should be
	3........	57. 0	taken.
	4........	65. 10	
	Green Mt................	82. 30	
	Prospect-hill	283. 00	Do.
	Inner tangent town and bend near Flat I.............	292. 21	
	Tangent	293. 49	
	Flat Island station	296. 0	Do.
	Tangent	297. 30	
	N. steeple	295. 35	
	Black-head mark	304. 25	
	Tangent head	307. 10	
	Rocks off, 312° 5′ *awash*..	317. 0	
	Tangents of cove 317° 5′ to	319. 15	
	Grassy Pt. station	321. 0	
	Bluff..........	323. 15	
	Skiff....................	320. 12	
	Bluff..........	324. 36	
	Summer H. battery staff....	325. 0	
	Tang. bluff under ruin battery	330. 0	
	Angle of battery......	333. 0	
	Pt. of Peninsula..........	345. 0	
	Staff on Peninsula and Martello	349. 5	
	Snipe....................	322. 10	
	Red Pt.	351. 50	
	Cricket	356. 15	
	Lines and batteries.		
	Flag of upper blockade	32. 0	
	Lower	34. 36	
	Town lines, N.E. tangent ..	289. 36	
	N. angle 293° 17′ reced. ang.	299. 7	
	Angles of 1st bastion 303° 48′	304. 25	
	305° 5′................	305. 20	
	Do. of 2nd 310° 21′	311. 21	
	Flag 311° 52′	312. 32	
	Landing-place 313° 15′ to..	313. 46	
	West angles 314° 21′ to....	315. 20	
	S.W. extremity ..	316. 30	
	Zero correct .... Mag.	136. 58	

No. 4.—October, 1832.
GRASSY POINT.

Date.		
31	Zero, Black Cross, Mag.	37° 33′ 40″
	Slaughter-hill	4. 25. 0
	Tang. Pt. Peninsula ...	6. 10
	Cricket Pt............	17. 20

Date.	No. 4.—October, 1832. GRASSY POINT—*continued.*		
31	Red	27° 55′ 0″	
	Tang. skiff Bluff	33.40	
	Crown barren Mt. 30° 0′ to	35.15	
	Mt. Misery	41.45	
	Black head. tang.	50.45	
	Black head. station	52.30	
	Black head. rocks off	48.00	
	Black head. *awash*	44.24	
	N. steeple	90.35	
	High do.	97. 5	
	Prospect-hill	127.00	
	Danger island	180.40	
	Cliff mark for coastline.	105. 0	
	Boat-house do.	207.30	
	Garret window do.	226.30	
	Summer-house battery.	230.55	
	Ruin battery	261.30	
	Martello. Tang.	291.25	
	Martello. Flag.	292. 0	
	Martello. Tang.	292.35	
	St. Juan's town. Tang.	318.45	
	St. Juan's town. Steeple.	324.12	
	St. Juan's town. Tang.	326. 5	
	Bluff under	328.10	
	Tang. Martello Bluff	296.30	
	Rocks off	304.20	
	awash	309.20	
	Tang. Creek Bluff and island, inner	315. 5	
	Tang. Is. and opp. cove	318. 5	
	Windmill-hill	324.10	
	Bluff under	330. 7	
	Tang. Grassy Island 330.37 to	338.30	
	Blockade Fort flag	334.10	
	Lower do.	339.30	
	Extreme of S. Pt.	342.18	
	Sandy Tongue	347.55	
	Tang. Pen. 351° 25′ brow	354.20	
	S.W. angle of lines *51° 15′, flag	60.00	*Mark on wall.
	Flank battery 58° 30′, 61° 17′	62.25	Receding angle.
	South angle works	71.25	
	S.E. bastion 103° 23′ 105 5	106.10	Next ang. in line.
	108° 0′ reced. ∠ Gate battery	108.25*	*Mark erected for base.
	Blockade 333° 15′ to.	334.40	
	Lower do. 338 48 to.	339.55	
	Zero correct. Mag.	37.33.20	

Date.	No. 5.—October, 1834. PROSPECT HILL.		
31	Zero, Black Cross. Mag.	66° 12′ 20″	
	Slaughter-hill	6.22	87° 34′ 0″ 34.10 d. 34.20 34.40 r.

Date.	No. 5.—October, 1832. PROSPECT HILL—*continued.*		
31	N. steeple	7° 37′ 0″	
	N. tang. town	15 22	
	Black Bluff mark	21.52	
	Bluff tangent	20.15	
	Rock *awash*	17.30	
	Tang. depth of bay	23.45	Z. D.
	Mount Misery	32.20	89° 4′ 20″ d. 4.30 5. 0 r. 4.30
	Cliff mark, S. shore.	266.55	
	Summer-house battery.	297. 5	88.55.10 d. 55.40 56.40 r. 55.50
	Boat-house	281.55	
	Garret-window	298.30	
	Ruined fort	318.40	
	Tang. Bluff	320.10	Z. D.
	Martello flag	328. 8	87.42.10 d. 41.50 43.00 r. 42.20
	Grassy station	335.35	83.41.10d. 40.50 41.40 r 41.50
	St. Juan's. Tang.	343.22	88.13.30 d. 12.50 12.40 r. 13.00
	St. Juan's. Steeple.	345.23	
	St. Juan's. Tang.	346.20	
	Bluff under	347.30	
	Windmill-hill	347.12	
	Bluff tangent	350.10	
	Grassy Pt. 349° 20′ to	353.25	
	Tang. Peninsula	353.56	
	Brow	355.47	
	Blockade flag	353.25	
	High steeple	358.37	
	N. steeple	6.37	
	Lines of Town.		
	N. ∠	16.38	
	S.E. bastion ∠	345.23	
	346° 30′ receding.	347. 5	
	Town Gate battery	351.55	
	354° 5′ and	354.45	
	Angle of works seen over	349.15	
	East Bastion	359.16	
		1. 5	
		4. 5	
	Memo. Line of Zero runs through the main street—a mark on the parapet in line.		
	Zero. correct. Mag. 67° 12′ 00″		

Date.	No. 6.—October, 1832. SLAUGHTER HILL.		
31	Zero. Black Cross. Mag.	199° 54′ 00″	
	Summer-house battery.	8. 29. 40	
	Tang. Pen. brow......	9. 30	
	Cliff..........	14. 42	
	Martello Bluff 28° 22′ to	38. 20	
	Martello Tr. { Tang...	33. 0	
	Flag ...	33. 26	
	Tang...	33. 55	
	Rocks off 28° 0′ *awash.*	30. 21	
	Creek Bluff tangent...	44. 43	
	Island 54° 45′ ......to	59. 45	
	West tangent creek ...	58. 38	
	St Juan's . { Tang. ..	61. 55	
	Steeple.	67. 44	Z. D. door.
	Tang...	69. 41	
	Ravine and tang. Bluff	83. 40	
	Next do............	92. 45	
	Windmill............	88. 16	
	Grassy Island 77° 10′ to	98. 30	
	Extreme Pt. of main..	115. 50	
	Sandy Tongue	122. 30	
	Beach marks for coast-line........ 1.....	93. 50	
	2.....	102. 0	
	3.....	110. 17	
	Tang. N. Bluff.......	146. 50	
	Edge ..	148. 50	
	Fort William { Turrets 1.	151. 45	
	2.	153. 33	
	Flag staff .	155. 50	
	Turret 3.	156. 40	
	4.	158. 15	
	Tang. brow Peninsula	160. 15	
	Do. cliff ..	163. 15	
	Pap cliff....	165. 0	
	Paps........1.......	201. 15	
	2.......	214. 10	
	3.......	197. 35	
	4.......	181. 00	
	Base flags two, W. ..	355. 0	
	two, N.E...	274. 6. 24	
	E.....	285. 0	
	S.....	315. 0	
	Mount Misery	261. 4	
	Snipe................	285. 21	
	Red Pt..............	287. 20	
	Black Head { Tang...	296. 40	
	Mark...	299. 17	
	Tang...	303. 30	
	Rock, *awash*.........	301. 30	
	Flat Island	314. 50	
	Tang.......313° 47′ to	317. 0	
	Tang. town..........	315. 50	
	N. steeple	319. 55	
	Skiff bluff tang.	326. 50	
	Mark	327. 25	
	High steeple	324. 22	
	Prospect hill	320. 2	
	Tang. penin. pt.......	344. 24	
	Grassy station	346. 40	
	Tang. bluff	348. 36	
	to	344. 0	

Date.	No. 6—October, 1832. SLAUGHTER-HILL—*continued.*		
	Lines of Town, and Blockade Batteries.		
	Upper blockade fort-flag .	105° 22′	
	Tang.................	104. 30	
	Ang. (2 guns, 24 prs.)	105. 22	
	Ang. (3 „ „)	105. 57	
	Lower do. tang. (1. 24 pr.)	111. 0	
	Flag..........	111. 50	
	Ang. & tang. (3 of 24 pr.)	112. 30	
	Town.		
	N. ∠ works	315. 3	
	Receding ang. lines......	318. 45	
	Outer ang. of bastion (1)..	319. 50	
		320. 22	
		320. 41	
	2nd bastion ang.	321. 33	
	Flag. and ang. in line	322. 45	
	Ang. west bastion ...... (on with ang. of landing.)	323. 15	
	West ang...............	324. 5	
	South..................	325. 45	
	Flank	330. 30	
		330. 46	
		331. 50	
	S. ang. of works	334. 2	
	Gap of Grassy bluff......	342. 45	
	to	344. 12	
	Zero correct .. Mag.	199° 54′ 20″	

Date.	No. 7.—November, 1832. GREEN MOUNT.		
1	The only station seen on north side is Mount Misery; St. Juan's on the south.		
	Zero. Mt. Misery. Mag.	234° 21′ 40″	
	Summer-house battery.	49. 52	
	St. Juan's steeple .... (seen over pap. 1.)	85. 49	
	Head of staff, Fort Wm.	121. 55. 30	Just seen.
	Windmill hill	100. 24. 0	
	Tang. Partridge Id. ..	158. 10	
	Shag rock station	168. 58. 30	
	Tangts.......168° 6′ to	170. 0	Rock in line
	Partridge pt.	163. 40	
	Sharp pt. (white)	165. 45	
	Tang. pen. bluff......	112. 30	
	Pap bay bluff	120. 10	
	Paps .... 4....	66. 43	
	2....	83. 57	
	3....	103. 15	
	1....	85. 49	

Date.	No. 7.—November, 1832. GREEN MOUNT—*continued.*		
1	Sandy tongue	108° 30′	
	Blockade (flag)	110.33	
	lower do.....	111.10	
	Pt. in watering bay ..	148.40	
	Zero correct .... Mag.	234.21.40	

Date.	No. 8.—November, 1832. FORT WILLIAM.		
1	Green Mt. not visible, Slaughter-hill only North Station in sight.		
	Zero. Slaughter. Mag.	227° 25′ 20″	
	Ruin battery bluff	22.30	
	Battery	24. 0	
	Martello bluff	34.18	
	Rock, *awash* ..	31.38	
	Summer-house battery .	24.20	
	Martello { Tang.	37.15	
	Martello { Flag.	37.40	
	Martello { Tang.	37.55	
	Creek Pt. and Ravine of Martello	40.40	
	Creek bluff, west tang.	45.15	
	Tang. Id. (seen over).	46.40	
	St. Juan's { Tang. ..	47.56	
	St. Juan's { Steeple ..	52.15	
	St. Juan's { Tang. ..	55.42	
	Windmill bluff	67.26	
	West tang. Grassy Id. and Windmill	75.50	
	Long tongue (sand) ..	72.22	
	Beach marks .... 1....	80.43	
	2....	84.40	
	3....	88. 8	
	Blockade battery	88. 7	*Upper same.*
	Ang.	89.10	
	Flag and ang.	90.40	
	Tang.	92.00	Do. lower.
	Staff of lower .... } Extreme low pt. in line }	89.22	
	Outer tang. 2 pts. in line	96. 6	
	Rock off	97.30	
	Shag rock { Tang. ..	224.50	
	Shag rock { Station .	225.43	
	Shag rock { Tang. ..	226.50	Do. of Quail
	Partridge point	244. 0	
	Inner tan. Partridge ..	241.56	
	Partridge mount, mark	250.25	Rejected st.
	Sharp point, white	271.20	
	Point of watering bay .	282.52	
	Cliff of do.	285.36	
	Paps......... 4....	298.43	
	3....	313.20	
	2....	322.43	
	1....	340.53	
	Tang. of bluff of do. ..	9.25	
	Zero correct .... Mag.	227.25.20	

Date.	No. 9.—November, 1832. SHAG ROCK.		
2	Zero. Green Mt. Mag.	181° 37′ 10″	
	Tang. coast, northward	339.30	
	Bay mark, Partridge Pt.	358.45	
	Point watering bay ..	6.36	
	Stream .	7.38	
	Paps............ 4....	18.12	
	2....	19.35	
	3....	30.56	
	1....	40.17	
	Pap. bluff	25. 4	
	Tang. fall of cliff......	46.15	
	Slaughter bluff	47.41	
	St. Juan's steeple	71.19	
	Tang. main	48.46	
	Peninsula.......	52.45	
	Bluff	55. 7	
	Fort Wm. { Turret 1....	62.13	
	Fort Wm. { 2....	64.36	
	Fort Wm. { & Flag. 3....	67. 5	
	Fort Wm. { 4....	69.10	
	Outer pen. tang.	70.23	
	Water line and rocks off	73.25	
	Sandy Tongue	78.15	
	Blockade Fort (flag) ..	94. 8	
	Lower do. ..	90.22	
	Pt. 96.25 rock off....	97.30	
	Outer extreme point ..	102. 0	} Seen from Fort Wm.
	Grassy Id. tang.	84.40	
	Inner tang. Pt.	87.20	

Date.	No. 10.—November, 1832. DANGER ISLAND.		
2	Grassy Point Station, visible.		
	Zero. Grassy Pt. Mag.	40° 3′ 20″	On basalt.
	Cliff mark	220. 8	
	Summer-house battery.	288.40	
	Boat-house	260.35	
	Garret window	296.10	
	Ruined fort..........	324. 0	
	Bluff of do..........	325.17	
	Bluff of Martello......	327. 0	
	Martello flag	324.52	
	Rocks off............	332. 0	
	awash	336. 8	
	Creek bluff	335.12	
	Island	335.23	
	St. Juan's tang.	339.47	
	Steeple	338.15	
	Tang. town bluff, and Grassy Island......	341. 3	
	Blockade batt. (flag) ..	341.46	{ 341.10 tang 342.15 tang
	Lower do. (flag)	345.40	
	Tangents .. 345.11 to	346. 0	
	Slope under	347.36	
	Sandy Tongue	351.25	
	Tang. Bk. cross penin.	355.40	
	Grassy Pt.	357.46	
	Zero correct .... Mag.	40. 3.20	

Computation of the Main Bases from that measured.

Base measured 1518,9 feet, or one-fourth of a nautic mile.

As the angles throughout have been proved equilateral, with the exception of the right-angled triangle communicating with Black Cross station, we are at liberty to assume the continuous sides of adjoining triangles at double their measurement.

Then, taking the side $a\ d = 1518{,}9$; $d\ e = 3037{,}8$.

To find the angles.*

The sides being continuous of two equilateral triangles, and one side a base, it follows that the included angle equals 120.

As sum of sides 4556,7 co. ar. ...	6.341349
: diff. 1518,9	3.181530
Tang. ½ sum ∠s = 30°	9.761439
: tang. ½ diff. 10° 53′ 36″	9.284318

120° — 180° = 60° ÷ 2 =	30°
	10° 53′ 36″
Opposite lesser side ..	19. 6.24
Opposite greater side ..	40. 53. 36

Then for the side *e f*.

As 40° 53′ 36″ sine co. ar.	0.183989
: *d f* — 3037.8	3.482559
: 120° sine	9.937531
e f = 4018.64	3.604079

We have now to obtain the side, *e* Black Cross. The two sides included by the right angle are equal, therefore the other two angles are each equal to 45°.

As rad.	0.000000
1518.9	3.181530
: : sec. of ∠ 45 ..	0.150515
e † = 2148.05 ..	3.332045

Sides ..	4018.64
	2148.05
Sum ..	6166.69
Diff. ..	1870.59

Angles at *e* ..	40° 53′ 36″
	45
∠ *f e* † =	85. 53. 36
— 180° =	94. 6.24
½ sum ∠s ..	47. 3.12

As sum sides, 6166.69 co. ar.	6.209949
: diff. 1870.59	3.271979
: : tang. .... 47° 3′ 12″	10.031154
Tang. ½ diff. 18° 3′ 2″.5	9.513082

½ sum ∠s	47° 3′ 12″
½ diff.	18. 3. 2.5
Opposite gr. side ..	65. 6. 14.5
Less do. ..	29. 0. 9.5

Then for the side † *f*.

As 65° 6′ 14″.5 cosec.	0.042357
: 4018.64	3.604079
: : 85° 53′ 36″	9.998884
: † *f* = 4418.99	3.645320

* Where the survey is thus carried on, it is preferable to use the computed *internal* angles, as they cannot be measured accurately.—*Vide* Lines of Base, Plate VIII.

TABULATION OF TRIANGLES, &c.

*** The remaining stations have been worked on the same principle as before shown in the survey afloat; the results are tabulated.

Station.	No.	Angles.	* Base opposite.	In Feet.	Logarithm.	Ref.	Cor. Cur.
		° ′ ″				″	″
Black Cross	1	57. 52. 45	Flat Id. to *f*. N.E. flag	6374. 85	3. 804470		
Flat Island		35. 57. 0	Black Cross to N.E. flag	4418. 99	3. 645320		
f		86. 10. 15	Black Cross to Flat Id.	7510. 20	3. 875653		
Mount Misery ..	2	60. 15. 0	Flat Id. to N.E. flag ..	6374. 85	3. 804470		
Flat Island		20. 3. 0	Mt. Misery ..	7237. 60	3. 859597	5. 90	1. 25
N.E. flag		99. 42. 0	Mt. Misery ..	7237. 60	3. 859597		
Mount Misery ..	3	64. 0. 0	Black Cross to Flat Id.	7510. 20	3. 875653		
Flat Island		56. 0. 0	Mt. Misery	6927. 35	3. 840567	5. 70	1. 15
Black Cross		60. 0. 0	Flat Id. to Mt. Misery	7236. 40	3. 859524		
Slaughter-hill	4	53. 46. 0	Flat Id. to Mt. Misery.	7236. 40	3. 859524		
Mount Misery ..		82. 4. 0	Slaughter ...	8885. 47	3. 948680	7. 31	1. 89
Flat Island		44. 10. 0	Slaughter to Mt. Misery	6250. 80	3. 795933		
Grassy Bluff	5	41. 45. 0	Black Cross to Misery .	6927. 35	3. 840567		
Black Cross		99. 15. 0	Grassy .... „	10268. 00	4. 011486		
Mount Misery ..		39. 00. 0	Grassy to Black Cross .	6547. 00	3. 816042		
Prospect-hill	6	56. 45. 0	Grassy to Mt. Misery .	10268. 0	4. 011486		
Grassy		85. 15. 0	Misery to Prospect ..	12236. 0	4. 087637		
Mount Misery ..		38. 00. 0	Grassy .... „	7559. 15	3. 878473	6. 18	1. 368
Slaughter-hill	7	58. 58. 0	Misery to Prospect ..	12236. 0	4. 087637	10. 08	3. 584
Prospect		25. 58. 0	Slaughter ...	6250. 80	3. 795933		
Misery		95. 4. 0	Slaughter to Prospect .	14224. 0	4. 153023	11. 70	4. 843
St. Juan's steeple .	8	52. 12. 0	Grassy to Mt. Misery .	10268. 0	4. 011486		
Misery		50. 15. 0	Steeple	9991. 05	3. 999611		
Grassy		77. 33. 0	Steeple to Misery	12689. 3	4. 103439		
Green Mount	9	85. 49. 0	Steeple to Misery	12689. 3	4. 103439		
Mount Misery....		71. 15. 0	Green......	12048. 1	4. 080916		
Steeple		22. 56. 0	Green to Misery	4957. 74	3. 695774		
Slaughter-hill	10	85. 36. 0	Grassy to Mt. Misery .	10268. 0	4. 011486		
Misery..........		57. 4. 0	Slaughter ..	8643. 46	3. 936687		
Grassy		37. 20. 0	Misery...... „	6250. 80	3. 795933		

* Or that made use of.

Station.	No.	Angles.	Base opposite.	In Feet.	Logarithm.	Ref.	Cor. Cur.
		° ′ ″				″	″
St. Juan's	11	58.43. 0	Grassy to Slaughter ..	8643.46	3.936687		
Slaughter........		81. 4. 0	Slaughter to St. Juan's.	6530.35	3.814936		
Grassy		40.13. 0	St. Juan's.	6530.23	3.814928	Old Base.	
Fort William	12	52.15. 0	Slaughter to St. Juan's.	*6530.29	3.814932		
St. Juan's		39.39. 0	Fort Wm..	5270. 0	3.721812		
Slaughter		88. 6. 0	St. Juan's .. „	8254.44	3.916687		
Green Mount	13	†68. 9.30	Slaughter to Mt. Misery	6250.80	3.795933		
Mount Misery ..		64.26. 0	Green Mt..	6074.80	3.783531		
Slaughter		47.24.30	Misery ...... „ ...	4957.74	3.795933		
Fort William	14	‡68.24.30	Slaughter to Green Mt.	6074.80	3.783531		
Green Mount		53.46. 0	Fort Wm. .	5269.80	3.721794		
Slaughter		57.49.30	Green to .... „	5530.10	3.742734		
Shag Rock	15	71.19. 0	Green to St. Juan's ..	12048. 1	4.080916		
Green Mount		83. 9.30	Shag to St. Juan's	10031. 0	4.001326		
St. Juan's		25.31.30	Green to Shag Rock ..	5480.34	3.738808		
Shag Rock	16	67. 5. 0	Green to Fort William	5530.10	3.742734		
Green		47. 3. 0	Shag to Fort William .	4394.60	3.642921		
Fort William		65.52. 0	Green to Shag Rock ..	5479.20	3.738719	§	
Blockade batt. ..	17	39.12. 0	Slaughter to Fort Wm.	5269.80	3.721794		
Fort William		90.40. 0	Blockade ..	8337.90	3.921057		
Slaughter........		50. 8. 0	Fort Wm. to Blockade.	6399.66	3.806157		
Summer-house bat.	18	37.35. 0	Grassy to Prospect....	7559.15	3.878473		
Grassy		103.55. 0	Summer-house to do...	12030. 0	4.080265	9.90	3.464
Prospect-hill		38.30. 0	Grassy .	7715. 3	3.887354		
Danger Island ..	19	71.20. 0	Summer-ho. to Grassy .	7715. 3	3.887354		
Grassy		50.15. 0	Danger to Summer-ho.	6261. 2	3.796659		
Summer-ho. batt.		58.25. 0	Danger to Grassy	6937.45	3.841200		
Summer-house ...	20	62.15.20	Prospect to Slaughter .	14224. 0	4.153023		
Slaughter-hill		48.27.40	Summer-ho.	12029. 9	4.080259	‖	
Prospect		69.17. 0	Slaughter............	15032. 6	4.177034		
Black Cross	21	70.40. 0	Misery to Prospect ...	12236. 0	4.087637		
Prospect		32.20. 0	Black Cross to Misery .	6935. 4	3.841072		
Misery..........		77. 0. 0	Prospect to Black Cross	12634. 8	4.101569	10.38	3.82
Prospect	22	46.57. 0	St. Juan's to Misery ..	12689. 3	4.103439		
Mount Misery ..		88.15. 0	Prospect..	17356. 5	4.239462	14.28	7.212
St. Juan's		44.48. 0	Misery...... „	12236. 0	4.087637		
Martello	23	68.22. 0	Prospect to Slaughter .	14224. 0	4.153023		
Prospect		38.14. 0	Martello .... „	9469. 8	3.976341		
Slaughter........		73.24. 0	Prospect ..	14664. 2	4.166257	11.76	5.147
Flat Island		.. ..	St Juan's door computed	12931.6	4.111653	10.64	4.00
Black Cross......		.. ..	Slaughter hill, 1st comp.	2148.05	3.332045	1.74	0.11

* Mean base.

† Computed from sides for proof.

‡ Computed from sides.

§ Proof of former triangle.

‖ Proof by greater angle than No. 18.

DETERMINATION OF HEIGHTS.

Stations.	Height Eye.	Object.	Dist.feet.	Logarithms.	Alt. or Dep.	Corrections. Ref.	Curv.	Diff. level.	Mean level.
	feet.				elev.				
Flat Island ..	14	Mount Misery .	7237,60	3.859599	∠5° 39′ 7,5″	5,90″	1,25	716,1	731,25
		Slaughter-hill . .	8885,47	3.948680	∠2. 1.52,5	7,30	1,89	314,8	330,7
		St. Juan's . .	12931,60	4.111653	∠1.39.35,0	10,60	4,00	374,1	392,1
Black Cross .	20	Mount Misery .	6927,35	3.840567	∠5.51.12,5	5,70	1,15	710,0	731,1
		Prospect-hill . .	12634,80	4.101569	∠4. 4.38,9	10,38	3,82	900,5	924,32
		Slaughter-hill .	2148,05	3.332045	∠8.12.45,0	1,15	0,11	310,0	330,1
					dep.				
Prospect-hill.	928,32	Mount Misery .	12236,00	4.087637	⦣0.55.25,0	10,00	3,58	196,67	731,23
		St. Juan's . .	17356,50	4.239462	⦣1.47. 0,0	14,20	7,27	539,06	392,47
		Grassy . .	7559,15	3.878473	⦣6.18.37,5	6,20	1,37	835,69	90,00
		Summer-ho. batt.	12030,00	4.080265	⦣1. 4.17,5	9,90	3,46	224,43	707,35
		Martello . .	14664,20	4.166257	⦣2.17.40,0	11,76	5,15	586,7	348,77
		Slaughter . .	14224,00	4.153023	⦣2.25.42,5	11,70	4,84	602,44	330,72

We will now proceed to determine the mean variation, as diffused throughout the general mass operated on; that determined at the observatory being possibly affected by the locality, as a landing place for stores of iron, casks, ballast, &c.

Having the true bearing of Flat Island, from Black Cross station, the others naturally result. We will, however, introduce an example at Flat Island. The zero bore S. 79° 21′ 3″ W. − 180° = 100° 38′ 57″ = true N. Now, the magnetic at Flat Island.

76° 57′ 00″	Mag.
100. 38. 57	True.
23. 41. 57	Var. W.

Finding the true bearing of each zero, the following positions will be found to give the annexed variations.

At Black Cross................	23° 43′ 57″	
Flat Island..................	41. 57	
Mount Misery................	40. 47	
Prospect Hill	46. 47	
Grassy Station	50. 27	
Green Mount.................	47. 17	
Slaughter Hill	44. 17	
Fort William	40. 37	
Shag Rock	45. 53	
Danger—rejected		20. 40. 37
	9) 401. 59	
	23. 44. 39,9	
Mean at observatory	45. 10	

The next important parts of the work are, the soundings, delineation of shoals under two fathoms, three fathom line, and marks for avoiding dangers. The inner harbour will be our first consideration, as being remote from range of enemy's guns. In performing such service it is not sufficient to say, "You are to sound out this space." It must be methodically arranged, in order that the principal may know when the work is complete, or what further is required. In performing this, let the bay stations be roughly protracted to four times the size on cartridge paper, the daily orders guided by it, and the soundings laid down. When complete, reduce this, by "squaring off," and insert it in the plan. All dangers should be verified on the original rough. In speaking of "*rough*," the *original* should always bear *examination*, and be kept nearly as perfect as a *finished* copy. This can be done by moderate attention. We will now introduce the soundings, which will serve for practice (by tranferring the stations to a rough sheet, and increasing the dimensions.)

That selected is what would be considered *moderate* work for one boat in the course of the day. Say from 6 A.M. to 6 P.M., allowing one hour for dinner, and that a breeze favours two-thirds of the distance. Twenty lines, of one mile each, might thus be reckoned on, [although it has been found seven boats can average twenty-five in a strong tideway and open sea.] The dots show the lines of soundings, which on four times the scale would have found room. It is evident, from the plan, that the principal can take sure measures for crossing the lines sounded, by another boat, without the risk of their falling on the same lines (by causing her traverses to run N.N.E. to S.W.) and may almost cover the space with figures. The soundings being the *most important part* of the plan to the *seaman*, too much nicety cannot be observed in following out the *particular lines on tangents of the coast*, or two headlands, or conspicuous objects, in line. Eventually these may become the leading marks for avoiding dangers; and strange it is, that in almost every intricate channel, nature has so placed her objects, that it might almost be imagined they were designed for such a purpose.

In determining the limits of a detached shoal, it is requisite to stand off into several casts beyond its boundary, and on to the same, if it is not to be crossed. The operation is tedious, it is true, but the *test* of the work is that *beneath the surface.* Any draughtsman may make a neat shewy plan, but it is useless if it cannot stand the *seaman's test.*

It is not to be imagined that this duty is to be left, as a matter of course, to assistants. Judicious lines of sounding, particularly in closing sailing directions, should be taken by the *principal*, and wherever any discrepancy in the work leads him to doubt, that doubt should be resolved by *himself*. Few will find fault with the land within; but should an unlucky dependence on the labours of others ground one of his Majesty's ships, or even a merchantman, no excuse, *however perfect, will save his character*.

When it is practicable to land near the shoal to be examined, and ground adapted, the operation is much assisted (*and time eventually saved*) by placing six stakes, forming a hexagon. Take the angles between any two extremes to the rest, and to three objects connected with the main triangulation. Construct a hexagon by eye, and draw lines to all points. Now it is evident, that each object within the hexagon, if truly placed, would be cut at an angle of 90°, and the positions for the two stations taken from the plan, and increased in dimensions on cartridge paper, (say quadruple,) will afford a very satisfactory and cleanly way of performing this operation, the angles being taken to the stakes only. This method affords a test, where rapid tides are involved, that time is not lost by going over the *same spot a dozen times*, particularly if in search of a rock, (which may be swept,) for we have no less than thirteen lines of direction included within the boundary of 120 degrees, which will clearly point out whether the boat pursues her intended course, or is swept away by tide.

SOUNDINGS IN INNER HARBOUR.

November 2, 1832.—Sounded as per instructions on following lines.

Line 1	Black cross towards Black-head rock (awash) . 2 . 3 . . 3½ 4 . . 4½	Angles, west and south base flags in line Angle to Flat Island .... 110° 6′
	5 . . . 5½ . . (E. and N. flags in line) 5½ . 6 Ang. to Flat Is. 116.40	S. flag and Slaughter in line. Martello over tang. Penin. Town flag, & high steeple in line.
		° ′
	6 . . 6½ . . . 7 . .	Grassy and Prospect .. 48.42 Prospect and Misery .. 107.10
	7 . 6½ . 6 . 5½ 5 .	Black cross and Grassy . 77.55 Grassy and Prospect .. 52.52 Flat in line.
	5, 4, 3 . Same 74° 36′ / 54.20 3 2½ 2 . at rock.	
No. 2	Westerly, keeping E. and W. base flags in line 2 . . 3 . . 3½ . .	Objects in line. Ang. to black cross 38.20
	3½ 4 . . 5 . . .	Tangts. of skiff and Grassy in line Objects in line. Angle to black cross 43. 0
	4½ . . 4 . . . 3½ . 3	Objects in line. Angle to black cross ...... 54. 5 Red point and N. flag in line.
	On, to beach . 3 . 2½ . . . . . . 2 . . 1 . ashore.	
No. 3	For Black-head mark 1½, 2, 2½ . 3 . 3½	Black cross and Flat Island 110.45 Flat Island and Misery 103.50
	4	Grassy and skiff bluff in line N. flag and black cross .... 66.37 Black cross and Flat Island 115. 0
	4 . . 3½ . . . 3	Same objects 55.15 115.55
	3 . . . 2½ . . . 2 . ashore.	
No. 4	For N. base flag 2 . 2½ . . 3 . . 3½	N. base flag and black cross 53.40 Black cross and Flat Island . 112.15
	3½ . . . 3	Same objects 59.36 107.55
	3 . 3½ . . 4 . 3½ . 3	Same objects 70.20 99.42
	3 . . 2½ . . . 2 . ashore.	
No. 5	To bight of Snipe Bay 2 . 2½ . . 3 . . . 3½	N. base flag & black cross 66.30 Cross and Flat Island .. 99.30
	3½ . . . 3 .	Same objects 61. 0 102.42
	3 . 2½ . . . . 2 . 1½ ashore.	

No. 6	To Snipe 1½, 2, 2½ . . . 3 . 2½ . 2 1½ at point.		° ′
	To rock awash 1½ 2½ . 3 . . . 3½	N. flag and cross..	56.23
		Cross and flat	110. 0
	3½ 3	Same objects	55.55
			116.51
	3 . . . 2½ . 2 . at rock.		
No. 7	To N.E. flag 2 . 2½ . 3 . . 3½	N. flag and cross..	57.27
		Cross and Flat ..	120. 0
	3½ . 4 . 4½ . 4 . . .	Same objects	63.48
			110. 0
	4 . 3½ . . . . 3 .	Same objects	69.50
			99.40
	3 . . . 2½ . . . . 2, 1½, 1 ashore.		
No. 8	To Snipe point 1, 1½, 2, 2½ . . . . . 2 . 1½ at point . on to Red.		
	1, 1½, 2, 2½, 2½ . 3 . . 3½, 3, 2½ 2 . 1½ . 1 at point.		
No. 9	To snipe bight 1½, 2 . 2½ . 3 . 3½	North flag and cross	80.25
		Cross and flat island	106. 5
	4 . . . . . . 3½ . . . . . 3 . same	North flag and cross	53.30
		Cross and flat	110.12
	3 . . . 2½ . . 2 1½ 2 at bight.		
No. 10	To Cricket point, keeping south base flag in line 1½ . 2 . 2½ . . . 3	North flag and cross	55.55
		Cross and flat	116.15
	3½ . 4 . . . 5 . Tangent skiff and Grassy in line, E. and W. flags, in line.	Black cross and objects	44. 5
	5 . 5½ . 6 . 5½ . 4 . 3½ . . 3	Cross and flat......	118. 0
		Flat and Misery....	86. 6
	3, 2½ . . . 2 . 1½ 1 at point.		
No. 11	To rock awash off Bk. head 1½, 2, 2½, 3 . 3½	Cross and flat......	120.25
		Flat and Misery....	85.30
	4 . 4½, 5 . . 5½, 6 . Red and N. flag in line	North flag and cross	76. 5
		Cross and flat	126.55
	5½ . . 5 . . 4½, 4 . 3½ . 3 . (within 2 casts of rock)* 2½ 2 . . rock.		
No. 12	Towards N. flag 2, 2½, 3, 3½, 4	N.E. flag and cross	68.10
		Cross and flag	111.35
	4 . . . 3½ . . 3	West flag and Grassy	108.50
		Grassy and flat	40.30
	3 . . . 2½ . . . 2, 1½ ashore.		
No. 13	To town flag 1½, 2, 2½ . 3, 3½ . . 4 . 5 5½	E. & W. base flags in line.	
		∠ to cross	47. 0
	5½	North flag and cross	62. 0
		Cross and flat	137.40
	5½ . 6	Black cross and Grassy	88. 6
		Grassy and flat......	69.50
	5½ . . . 5 . 4½ . 4 .	Flat and N.E. flag	121.12
		N.E. and cross ..	52. 0
	3½ . 3 . 2½ . 2 under fort.		

* When the lines of three fathoms have been frequently crossed near the same spot the angles may be omitted.

No. 14	Back, keeping red and N. flag in line 2 . 2½ . 3½	Flat and N.E. flag	117°15′
		N.E. and cross...	50.15
	3½ . 4 . 5 . . 5½, 6 . 6½ . 7 . . .	N.E. flag and cross	71.10
		Cross and Grassy	88.51
	7 . . . 6½	Same objects . . .	94.15
			79.40
	6 . . 5½ . . 5 . 4½, 4 . 3½ . 3 .	E. and W. flags in line	
		∠ to cross	54.25
	3 . 2½ . . 2 . 1 ashore at Red point.		
No. 15	For skiff mark 1 . 1½ . 2 . 2½, 3 . . 3½	N. flag and cross	125.35
		Cross and Black-head	69.50
	4 . . . . 4½ . 5 . 5½, 6 . 7 .	Grassy and Prospect .	48.40
		Prospect and Misery	107.45
	7	same objects	57.15
			110.45
	6½, 6, 5, 4, 3½ . . 3, 2 . 1 ashore under mark.		
No. 16	For E. base flag 1, 2 . 2½ . 3 . . 3½	Flat in line battery ∠	
		Flat and N.E. flag ..	104. 0
		N.E. and cross	57.10
	4, 5, 5½, 6 . 6½, 7	Town flag and high steeple in line	
		∠ to Misery	115.30
	7 . . . . 6½ (S. flag and Misery in line)	Cross and high steeple	114.40
	6½	Steeple and Misery ..	108. 0
	5½, 5, 4, 3½, 3 . .	Cross and steeple....	101.45
		Steeple and Misery ..	102.30
	3 . 2½ . . 2 . 1½ ashore.		
No. 17	To town flag 1, 1½ . 2, 2½ . 3 . 3½	Cross and steeple....	102.45
		Steeple and Misery ..	105.40
	4 . 5 . 5½ . 6 . 6½ . 7 . . .	Cross and Grassy....	89.30
		Grassy and flat	56.12
	7 . 6½ . . . 6 . . . Grassy and skiff in line, ∠ to cross		94.26
	5½, 5, 4½, 4, 3½, 2½, 2 . . . under fort.		
No. 18	To Cricket point, keeping town flag and steeple in line, 2½ . . 3		
	(Mem. The 3 fathom line here, is skiff Bluff and E.tangent St.Juan's in line)		
	4 . . 5 . 6, Grassy and Cricket in line. 6½ . . . 7		
	Town flag, and high steeple in line, ang. Black-head		66.45
	7 . . . . . 6½ . . . 6 same objects in line, angle to Misery		106.10
	6 . 5½, 5 . 4½ . 4 . 3½ . . 3 . same objects in line, angle to Misery		94.46
	3 . . 2½ . . . 2 . 1½ . at point.		
No. 19	To skiff station 1½, 2, 2½, 3 . 3½, 4, 4½, 5	South flag and Misery in line.	
		∠ to cross............	43. 5
	5½ . . 6 . 6½ . 7 N. steeple and Prospect, in line ∠ to Misery		97. 5
	7	High steeple and Misery	111.10
		Misery and Slaughter ..	71.48
	7 . . 6½ . . . . 6 Town flag and N. steeple in line, angle to Misery		104. 0
		(2 battery angles in line)	
	6 . 5½, 5, 4½, 4 . 3 . 2 . ashore.		
No. 20	To S. base flag 2, 2½ . 3 .	Town flag, and N. steeple in line	
	4 . 4½ 5 . 6 . . 7	Angle to misery	101.20
	7 . . . . . 6½ . . 6 E. and N. flags in line, angle to cross......		88.30
	5½ . 5 . . 4½, 4 . 3½ (Red and Cricket in line) 3, 2½, 2 . 1. Finished.		
		H. B.	

In drawing out directions for beginners, it is convenient to state the period which should elapse between the casts, allowing for the depth, &c. so that the soundings may be fairly disposed of on the paper. This too is material, when we take into consideration, that the soundings are not laid down by the person who takes them, and that in all hydrographic operations such a determined system, in all its parts, should be maintained, that the rough materials, when sent to the office, should be equally available as the day they were registered. To render this more complete, the person employed sounding should not only state his routes, as in these pages, but he should insert *every cast*, as it is only by taking the number between two sets of angles that they can be fairly applied in their proper place. The original order should be copied into the fair sounding book, allotted to each individual, as a future reference, in the event of the work being called in question, and that the credit, or blame, may be justly awarded. It is advisable, also, to state the reduction to be commenced with, and the time of high-water, which is obtained by the tide-book. In the survey of the Bijooga shoals, such were entered in the log, with the direction and force of the tide, as knots and courses.

By observations made in rapid rivers, I have found the fall of the tide vary in proportion as the embouchure has been confined or otherwise, and the level at one hour after high-water differ from that one hour before. The following is taken from the work of Mackenzie, and for all ordinary purposes is sufficiently correct.

AT SPRING TIDES.

At the 1st hour before and after high-water deduct	11-12ths	Of the full rise at springs.
2nd	3-4ths	
3rd	one-half	
4th	one-fourth	
5th	1-12th	
6th	0	

AT NEAPS.

At the 1st hour before and after high-water deduct	4-5ths	Of ordinary rise at springs.
2nd	3-4ths	
3rd	one-half	
4th	one-fourth	
5th	1-5th	
6th	0	

To do justice to the work, the officer who has sounded should reduce his work from the tide-book, taken at the precise times he was

thus employed, and not depend on the calculations of other places. In the event of freshes, he should be governed by the tide which has been *observed*, and that which ought to have taken place, from former observations when the moon had that age. [Cases have been known where the sea has remained at high or low tide during the whole twelve hours.] More tact and judgment is called for on this important part of a surveyor's duty than is generally supposed; and when it is considered, that an officer who zealously pursues this subject qualifies himself for a pilot; when danger calls for his services, he is then fully repaid.

The following data have been obtained from the examination of several registries of tides, where wind could not have had great influence, and the only fair law for general reductions would be; to reduce the soundings to low-water of the given day, corresponding with the mean decimal proportion on each hour, and from the result subtract half the mean difference (corresponding to the moon's age) from that at full and change.

As the variation in the rise and fall does not adhere to the differences, so clearly as the proportional rise during the hours, no such satisfactory conclusion can be arrived at; but the safer course will be, to fix on the excess generally, as our charts are seldom marked to less than the quarter fathom, and pilots only take into calculation the number of inches they intend risking.

The following has been deduced from the means furnished by the tide-gauge at Sheerness, the decimal parts being taken on different lunations, and parts of lunation.

Thus the means in one month commencing at 0 days:—

	1st hour.	2d hour.	3d hour.	4th hour.	5th hour.
☾'s age. 0 to 15th, give	0.12	0.34	0.59	0.79	0.92
and 15th to 29th	0.11	0.35	0.61	0.81	0.94
From which the mean	0.12	0.35	0.60	0.80	0.93 may be

safely taken.

The proportions for the difference between the *whole* rise at springs and each day of the moon's age, are as follows:—

☾'s age...	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Decimally	.000	.003	.008	.008	.009	.013	.019	.019	.027	.020	.017	.010	.007	.007	.000
or =		1-36	1-12	1-12	1-11	1-7	1-5	1-5	2-7	2-9	1-6	2-19	1-14	1-14	
☾'s age...	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
	.002	.005	.006	.013	.022	.030	.032	.042	.040	.035	.030	.022	.021	.015	
	1-53	3-21	1-16	1-7	2-9	2-7	1-3	2-5	2-5	2-7	3-10	2-9	2-9	2-13	

Reduce the depth to low-water of the given day, and subtract half the proportion answering to the above, which has been taken to inches and decimals.*

For any purposes connected with surveying, it is to be hoped that the above may be deemed fully sufficient, in the event of its being required to correct to *decimal parts of the foot*, but as before noticed, a quarter of a fathom is the lowest division on the chart, and the labour of investigating this question was rather with a view to show, that the observation thrown out relative to Mackenzie's scale for reduction, was not uncalled for. The error, however, would not exceed nine inches, or a foot, tested by the Sheerness diagrams.

Thus, on the 22nd day of the moon, one hour after high-water, the absolute height from the base of the diagram would give

	ft.	in.	
	15	4	
Rise 17 feet, four-fifths = 13.8	13	8	
Leaves	1	8	
But at springs the gauge shows only	2	9	as the lowest.
Diff.	1	1	
One day after the highest tide	18	0	
Rise 17.7 high springs 11-12ths =	16	2	
	1	10	
	2	9	
Diff.	0	11	

This is closer than we can expect to work in a seaway, and only where an absolute determination to carry a ship of war over a bar, to

* The whole rise at springs reduced to inches and decimals, is to be divided by the proportion answering to the ☽'s age, and half the result subtracted from low water of the given day.

gain an important advantage, calls for it, perhaps would not have been entertained.

One foot, however, is an advantage, which no surveyor under any circumstances, where a bar is concerned, *would overlook.* If not expressed on his chart, it certainly would be found in his sailing directions, forwarded to the authorities; although it is not at all times safe to publish all we know.

As reduction at the moment, is important, it may not be amiss to let the officer in charge of the tide department hoist distinguishing flags at the divisions of the tide. Then, as the rise for the day is known within an inch, and noted in the orders of those sounding, they will be enabled to perfect their work at once, noting the *times* at which the divisional flags were shown. Where rapid tides, swell, and other inconveniences, militate against the examination of a channel, through which doubt exists as to *special* draught, it has been found convenient to provide each boat with a spar of twenty-six feet or more, ballasted by a deep-sea lead. To the lead, within a foot of the ground, a spare lead-line should be attached, and the pole graduated from fifteen feet upwards. Pass the spar over the stern well to tideward, and steady it by the line to the stem; let the mark, + 1 foot of required draught, be kept at the transom, and watch the spar by hand, the boat being allowed to drift with her head in the *direction* of the tide, with slight headway, and the lead kept going as before. It is evident, that if any obstruction (which the lead missed) offers, the spar must be "brought up." Upon this system the bar of Oporto was proved, and many other channels have been examined; particularly on the uneven rocky bottom of the Bermudas.

Another simple plan [which was practised in sweeping for a schooner-rigged launch] is available for this purpose, and for determining the depth on bars where boats could not be risked. At the required depth attach to a baréca, a fire grapnel, or creeper, and anchoring the boat, thus supplied, in the lines of direction to be tested, watch the grounding of the baréca's anchor, and take simultaneous angles from two boats. It is evident, that by this method, a shoal, or bar, *in a tideway*, may be fairly examined when otherwise impracticable, as the depth may be gradually decreased, until that on which the break is, will be thus determined. The lead-line will of course bring it back to the boat. If ships carried in their binnacles leads attached to large pieces of cork, with line of six inches beyond their draught, it might instantly be determined, should they ground, if more

or less water was to be found in the direction of the tide, and before any boat could be lowered for the purpose.

They may even be thrown a considerable distance to tideward, by hand. The line should not exceed that of mackarel.

In closing the present remarks on sounding, it is to be observed that the symbols denoting the *nature* of the bottom have been purposely omitted, as the sole object is practice in laying down soundings from the angles. The directions on the subject of station pointer, apply to this duty. Whenever it is found requisite to compute a station from the bases and angles observed, it is either for a *distinct danger*, or as a position from which transit lines for points, &c. offer. Soundings are laid down by the instrument. The abbreviations for mud, sand, rocks, &c. will be found in the general table of abbreviations, and which in notation will be found very convenient; particularly in noting "rounds of angles," in which case, if the mind be intent on the subject, the whole series may present a pictorial definition. (Pl. VI.)

The methods of defining objects on the charts, are best referred to on the plans themselves.

Thus in plate I. the island is represented as bounded by an abrupt rocky cliff on its western side, but slopes to meet a sandy beach on the S. E. The crosses *without dots* in the quadrants are dangers *below* the surface, those with dots, denote rocks *awash*, as in the harbour survey, plate VIII. The sandy beach is also there defined on the south point; rock awash, off Martello. Grassy Island is represented as a marshy spot, which freshes, or highest springs, would nearly cover. All dangers are enclosed by a close dotted line; two-fathom shoals, by two dots; three fathom, by three dots, &c. A rocky *table* flat, as under Fort William; rocks dry at low water, as under Martello. Other objects are too obvious for further remark, excepting tides, or currents, outside a port. I have generally used the dart with the feathers on the side, on which the stream inclines to *press*, if thrown out of its line; as the ebb presses *off withal*, flood rather *bears on*. It does not follow that the flood *must* press *inwards*; there are many instances to the contrary.

The soundings being complete, we now turn our attention to those details, which under the circumstances we have proposed, would naturally be looked for, viz. the force of the opposite side, and advantages which may offer for attack.

Thus, as an example of the range and direction of guns, we will look to the blockade batteries, and determine at what

point they will act against an attempt on the town of St. Juan's. Next, supposing the Martello tower taken, if the town could be conveniently attacked. On a reference to the heights, it appears that the summit of Slaughter Hill is on the same level as the nearest houses of St. Juan, and out of range both of blockade and Martello. That of Martello can be taken, and a battery erected on Slaughter; the town and blockade battery must follow. Taking my telescope to the summit of Cross Peninsula, I found the extreme line of bearing to which guns could be brought, (viz. on the dotted line, vide plate VIII.,) and assuming a mile and a quarter as the range, in the event of their blowing away their works, the arc was dotted, to show that boats conveying troops could readily be kept out of danger. Having determined the faces of Summer-house battery, I also find that it is 360 feet above Martello, and can bring one gun to bear, (being just within range.) The question then arises,—will it be preferable to take the Summer-house battery first, keeping that at Slaughter masked, and thus by one manœuvre complete all; or, taking Martello, be forced to blow it up as untenable? It is possible the enemy may not attach the same importance to the Summer-house battery, and may thus afford the means of gaining what is required with less risk, by a retreat, spiking the guns, or knocking off their trunnions. This is to be deemed a necessary consequence of flight, or retreat; and measures should be taken in conjunction with the assault, when panic lends an incredible force to the invader, to replace the guns by those of the largest calibre. The shot tumbling on the Martello, the opening of the masked battery on Slaughter Hill, and the attack on the town, are enough to amuse the enemy for one day, and to give an imposing aspect to the vigour which may be expected from the assailants. Such is just the bird's-eye view which the plan offers. Those who are versed in the attack and defence of land positions, and whose province it is, may, of course, see many objections; but it is the *duty*, nevertheless, of the surveyor, to point out every weakness, every mode of attack, which occurs to him; and which no doubt he would be foremost to conduct. Without exercising the mind on such subjects, proper advantage cannot be taken of occasional visits to foreign possessions. From the instant an officer lands, until he quits the soil, of friend, or foe, his mind should register all such observations, and before going to rest (on board) commit them to paper. There are many positions which have successfully repulsed British ardour, that are comparatively defenceless when carefully examined in peace.

This subject has been introduced to illustrate the "*range and bearing;*" only one gun, it is true, has been brought into notice. At the point where the dotted line reaches, it is requisite to take two angles, one of which should be the battery flag; say Misery and flag, flag and Martello tower. We thus obtain a point to which a line is drawn from the battery, as the extreme direction. All the other guns might be similarly treated; but it is evident that even the practice awakens the mind to further contemplation.

Port for shipping.—Our next object, is to ascertain the number of ships which can conveniently ride in a state for service, (independent of merchantmen in tiers;) one hundred fathoms, *moored,* will be the diameter of a circle which will afford room for each ship to swing freely, her length never exceeding, when slack moored, 300 feet. Assume the most convenient marks for the main line, (say Town Staff and High Steeple,) and call that, the tier of frigates, or vessels of the largest class that can enter. Divide that line into 100 fathom distances; the same at right angles, omitting those within that distance of the shoal line, which will give the contents for vessels of war, the remainder affording ample space for merchantmen.

The next consideration is the roads, which must be distinctly classed; first, those on which carriages, waggons, &c. travel, their ascent on the mile, and what beasts are best adapted. Secondly, such as are used for mules, or which can be traversed by artillery. And lastly, those which are solely footpaths. These are all inserted in their proper characters. His observations may, however, enable him to suggest better lines for the convenience of transporting ordnance, and these should be designated by small circles and links, similar to the measuring chain, and be more particularly referred to in his "general statement."

Water.—The water should next occupy his attention, and he should fully ascertain how far the town is dependent on wells, or its conduction from the hills. Whether by turning, or cutting off the streams, they would be distressed, and how far this may be practicable.

Canals should be minutely detailed; the levels from lock to lock clearly followed out, and inserted on a separate sheet. In fact, all such details as would, if published on the marine plan, give reasonable, or even the shadow of offence, should be combined on a separate sheet, and be forwarded as one of the confidential details, a copy of which should be lodged at the Ordnance-office, until better materials be found. Should time admit, the survey of the land under cultivation

should serve as amusement and practical instruction for the younger branches, and will afford one source of approximating the resources, connected with the supplies which may be called for.

At what point water may most conveniently be obtained, and whether advisable to purchase, or obtain it by crew. If the beach admits of the near approach of ship or large boats, and whether the level would render it practicable to conduct it on board by hoses, provided the vessel veered in to her own draught.

Wood.—Wood, or fuel, is another consideration. Its market price, quality, and whether readily procured, or not. The consumption in the town, and in the event of siege, whether supplies are commanded by their guns.

The coin, rate of exchange, produce, imports, exports, and other points of commerce which may render it of importance—all these enter into the " remarks" which have been before treated on. Finally, the plan being complete, the sailing directions must be compiled, astronomical observations reduced and tabulated, and copies forwarded; the originals being reserved for some safe opportunity, when they will also be transmitted. In drawing up sailing directions, the strongest, most prominent features of the coast, should be selected, as affording the link connecting the *first sight of land*, to the anchorage in safety. If " long leading marks" from sea are available, it is some satisfaction to the mariner to know that he is steering his *direct* course, and on that line the pilot, if required, will be picked up. Such a leading mark offers in bringing the peak of Slaughter Hill in line with Prospect, which at high-water would be safe; but as the bar is approached, it will be necessary to open the hill between Slaughter and Fort, which will admit of the north steeple being seen,* on with the south turret of Fort William. This is one of the " bar marks;" but the surer, as noted on plan, is, staff of Fort William, on with Prospect, as fog or other causes may obscure the steeple. Stand on, until Partridge Island gapes with the main, and then shape a course for rounding the Peninsula. Scant wind may throw you towards St. Juan's flat. The marks are next to be found for avoiding this. The *safe* mark will be, the north, or *least* steeple, on with tangent of Peninsula Bluff. (*Vide* Plan.) The mark of *danger* (or two fathoms low water) will be, the Town flag on with the same Bluff. The limits easterly, slope of Fort William and south point of Partridge, Ruin Battery under Summer-house. The Martello shoal is lined, by Red and Peninsula points, and by the Creek

* " On with," nautical term, in line with

Island open of the town, as shown in Plan. The two steeples in line are *within* two and a-half low water, but avoiding this line, it will be safe to tack *short* of it.

Grassy Island and the extreme point, are on a line for the rock awash, off Martello, and the two steeples, are also the safeguard for it. The limits of the bar marks run as follow.

The north steeple on with the edge of the Bluff of Slaughter Hill cuts the extremity of the southern ledge.

Mount Prospect, and same Bluff, is safe at high-water for vessels of moderate draught, the outside current on flood making *northerly*.

The high steeple, on with the same Bluff, is a safe channel at half-flood (set northerly.)

Summer-house battery, over lower blockade, just clear of tangent of St. Juan's, may be made a long leading mark, and when close in, lines the south ledge.

The Martello tower, on with north tangent of St. Juan's, clears the south spit.

The same, on with foot of St. Juan's Bluff, *guards* the north ledge.

At high-water, the line of danger on the north ledge is, Fort William and Peninsula Bluffs in line.

Such then, *or upon such principles*, should sailing directions be framed. The pilot first considers the dangers at low water, the effects of a falling tide, and outside bearing of the current. These points being satisfactorily determined, he next takes into consideration, under the then state of the wind, what liberties he may take, depending on the set of the flood, and the depth he can carry at the time of tide.

The simple mariner is not supposed to attain this local knowledge, but by long servitude at the port; therefore all directions drawn out should distinctly avoid all *grazes*, and point out *clearly*, within what limits a ship may *safely steer*, as bad weather may induce him to venture when pilots cannot be had.

All bearings for the seaman should be given as compass, and to those who may be incautious enough to approach dangerous entrances, the *limits*, from which a vessel may *safely haul off*, without fear of indraught, should be stated, and the *most advisable tack*, so as, if possible, to make the set a *weather* current. This may appear straining the point, but experience proves otherwise, and the difference to a moderate sailing vessel of half point, on the weather, or lee-bow, is salvation or destruction.

Thus far, then, we may consider the surveyor's principal duty completed; the essentials, as latitude, longitude, variation, rise at springs, and neaps, views of land, from first appearance, with various marks on, up to the principal leading mark, being entered on the Plan.

There are various other little duties, which it may be in the power of the surveyor to execute, provided time and inclination, or course of study, lead him to pursue them. Geology he can materially assist, if he does not himself enter fully into the description of the geological features. He can take sketches of the cliffs, define their lines of stratification, and carefully collect the materials from each, for which purpose a few hints will be specially added hereafter. By inquiry amongst the inhabitants, he may ascertain what particular minerals are obtained in the neighbourhood, and probably collect specimens. If mines are worked, their value, expense in working, process, price of labour, how drained, or freed from water, or any other particulars, which may render it worth the attention of his own countrymen, or serve to introduce British capital. It should be his endeavour to make himself thoroughly acquainted with as much of the surrounding country as he is permitted to traverse. If the position be at the mouth of any river, he should ascertain how far it is navigable, to what height the flood is experienced, note places where bridges may be constructed, or are adapted for throwing troops across, whether the means are at hand, and how far the materials for carrying on any such operations are to be procured on the spot. Should the river be fordable at any point, he should particularly note it, and the nature of the bottom, if it can be ascertained. In many such situations, a naval officer in command of a pontoon party, transporting ordnance, or even conducting in person warlike operations with the marines of the fleet, may find, that his attention to such points in the early period of his servitude, has eventually obtained for him that preference from his chief, which his rank or seniority alone, could not possibly confer. The velocity of the stream (and method of finding which, will be here introduced) is not unimportant, and the volume and differences of level, of streams capable of turning machinery, should not be overlooked.

To determine the velocity of a stream, place two stakes in line; as nearly as can be judged, at right angles to the current. Pace 100 yards, and there place two similar stakes. Let the assistant go above the first marks, and throw a piece of wood into the strength of the stream, and watch at the stakes for its passing the line of direction,

holding his arm up, just when it is *coming* in line, and dipping it suddenly, as it passes. The principal, putting his watch to his ear, notes the beats until it passes him at the lower stakes; when the simple proportion, if 100 yards give so many beats, what will 9000 give, will afford the distance in yards for one hour; divided by 2025 = geographical; by 1760 = statute miles, (5 beats = 2 seconds, therefore 150 beats = 1 min.; and 150 × 60 = 9000.)

The great advantages, derived from using the beats, are twofold. In the first place, the division of the beat into tenths is very soon practicable. Secondly, the ear and eye are independent, both are intently at work; whereas the eye cannot watch both objects, in the event of measuring the seconds by eye.

If one person only, be present, place the lower stakes first, and pace to the upper position. Note the second when it passes, and run to the lower position, keeping the watch at the ear, then note the beat at its lower transit.

The laws, and port regulations, should occupy a conspicuous point in his remarks, that succeeding visitors may, by timely courtesy, meet with all the attention, foreigners when civilly treated, are ready to extend to British officers. It is not beneath the naval man to enter into the feelings and pride of a soldier; and when opportunity offers for military parade, he never should neglect such an opportunity, of personally inspecting the force which may perhaps too soon prove his adversary. The discipline, particularly the respect paid to their officers, the tone of command, and the bearing of the officers towards their men, are all strong grounds, which enable a close observer to estimate how they will behave in the field; for it must ever be borne in mind that the officers are superior in birth and intellect, and therefore should be in moral courage and determination. But if this be not duly appreciated by the men, all command in action is at an end, although no want of common courage exists in them; it is want of general discipline.

It will be here remarked, What has all this to do with Marine Surveying? It is not what the marine surveyor is, but what, by a fair system of education, and firmly sticking to the principles here advanced, he may make himself—a valuable assistant, and second to his chief, should he ever occupy the position of flag captain, captain of the fleet, (or eventually commander-in-chief.) It is not *merely* what the heads of departments *require*, that is looked for from the surveyor, but according to the *means* afforded, will government naturally look for *equivalents* in information.

LEVELLING.

We will now proceed to the next point of a surveyor's duty, although not frequently called for,—that of "Levelling." We have already determined the principal heights connected with the survey; but in parts where engineers, or other qualified persons are not found, and where they will not be sent, it may naturally be expected, that when the officer states such a place, "to be well adapted for the purposes of an arsenal," and speaking from his own personal knowledge, induces government to risk the public money on such an undertaking, that he can produce something more feasible than the mere hydrographical survey of that *part* of his plan. More than this will be looked for, and naturally. The materials, ability, and time, were not wanting; then why, if such an idea was *contemplated*, did not a special survey for this purpose take effect? Not because it is not part of a marine surveyor's duty. His duty embraces *all* he *can* do, and if he ventures to *suggest*, he should be prepared with some faint outline of his proposition. The features of the land are not the only requisites. The nature of the rock or ground to be operated on, must be tested from the specimens he produces. The rise of tide, depth at the beach, and means of increasing it, or adapting it, by carrying out works. Where the materials for these works are to be found. Whether lime (coral, shell, or limestone) is plentiful, and fuel at hand, for converting it to the purpose. The means of obtaining fresh water, and if wholesome. The adaptation of the soil for the purposes of cultivation, for field, or garden produce. And, finally, such facts, as shall convince the powers applied to, that such an undertaking will not require extraneous means, to sustain the population, beyond the mere expense of carrying on the works. In short, that the sum granted to complete the work, is not to be followed by an annual demand for the support of the population.

We will, therefore, proceed to show how the operations of levelling may be carried on by the surveying instruments usually employed, or by other means, where the abruptness and closeness of the work may call for it.

In the common practice of levelling, the simple level, constructed for that purpose, is made use of, but as the theodolite combines motion in azimuth, altitude, and level, the following observations will apply principally to it, but, it must be evident, are equally applicable to the level.

The system pursued in levelling, is of a different nature to that in marine surveying, and may be conducted with a very moderate portion of ability; but, where machinery, or other valuable property, is to be staked, requires considerable ability, skill, and character in the surveyor, before any such risk will be attempted. Levelling on the common scale, is conducted on lines, or sides of triangles; but where the ground becomes uneven, or obstacles continually compel the observer to have recourse to new lines of direction, it is obvious, that the work should be conducted on trigonometrical principles; and it is to combine the two that our efforts shall be at present directed.

Tapes, varying from 50 to 60, and 100 feet; chains, 66 or 100; rods, 10 to 12 feet; are made use of. The chain used by land surveyors is generally that of 66 feet, or imperial standard; and the following divisions of the acre result; acre = 10 chains, or 100,000 square links, of 7,92 inches each link.

We would have introduced a diagram here in illustration; but as this work purports to treat on marine surveying, it would be trenching too closely on land subjects. We will, therefore, suppose that the object the marine surveyor has in view, is the examination of a site in some foreign possession, with a view to the practicability of constructing an arsenal, or other public work. Let the following angles then be *protracted*, and we will proceed thence to conduct the process by the combination of simple levelling, and trigonometrical surveying.

Example.

Commenced measuring a base from Rope-walk station, towards watering Bluff. Rope-walk S., watering Bluff N.

Angles at Rope-walk termination.	Zero.	Watering Bluff.	Hospital Mount .. 60° 00′
			Pitch-hill........ 99. 15
„ Watering Bluff.	Zero.	Rope-walk.	Hospital Mount ..296. 0
			Pitch-hill.........321. 0
„ At Hospital.	Zero.	Rope-walk.	Watering Bluff .. 56. 00
			Pitch-hill not seen.
„ At Pitch-hill.	Zero.	Rope-walk.	Watering Bluff .. 41. 45
			Hospital not visible.

Now it is evident these angles cannot be mistaken, as the protractor, when placed at its zero, is the theodolite on paper.

The following Table exhibits the formula, which would be more in accordance with the practice of Marine Surveying, and possibly, may not be materially objected to by the engineer.

Objects left.		Zero or back.	Distances.	Height Eye.	Advance or 180.	Dep.	Elev.	Objects right.
To Cliff.	110		At ⊙	4.000	4.500	0.500		
	90	3.500	100 feet.	4.000	4.083	0.083		
	105	3.417	200 „	3.500	3.375		0.125	
	100	3.958	300 „	3.833	3.812		0.020	
	93	4.104	400 „	4.083	4.167	0.084		
	115	3.917	500 „	4.000	4.292	0.292		
	95	....	600 „					
	95	3.875	700 „	4.166	4.125		.042	
	100	....	800 „					
	100	3.875	900 „	3.833	3.500		.333	
	80	4.333	1000 „	4.000		.959	.520	
		4.404	1000 „	4.000		.520		
	And original zero from 1000=414+024=,438					.439, or 5¼ inches.		

By thus inserting, at every measurement, the elevation, or depression, the materials for projecting the profile of the ground, are ready for immediate use. Thus, the height at zero, or Rope-walk station, is 27 feet above the sea level; therefore the next station will be ,500, or six inches less = 26. 6, and so on in succession.

Now, the ordinary method of conducting this operation, is to place the instrument between two points measured, omitting the verification on every measurement. Such a process would exhibit the following, as taken from the above Table.

Back obs.	3.500	At 100 feet.	Advance	4.083
Omitting pos. 200 .	3.958	300 „	„	3.812
	3.917	500 „	„	4.292
	3.875	900 „	„	3.500
Sum back....	15.250		Sum advance	15.687
				15.250
			Diff. level..	.437

Now, as the decimals are merely the reduction of the inch to tenths, &c., the third figure is thus thrown out. In determining, therefore,

a length of such levels, where the profile is not very material, and the difference, at the extremities only, is required, this system is more expeditious, and requires less consideration.

The distances in the left-hand column of the table, under the head of "Objects left," are off-sets, at right angles to the measured base, and are the distances from that line to the cliff, by which its features are defined. ("Objects right," would have included any marks on the right of the base, as a road, ditch, fence, &c.)

Now, the ground between the other objects will not admit of measurement, being impeded by two bends of the river between Watering Bluff and Hospital, and being of a rough rugged volcanic nature, between Rope-walk and Pitch-hill. Stakes of *known height* were placed at the conspicuous parts of the profile, and the zenith distances, by a transit theodolite, obtained at the extremities of the base already measured. The three first, and nearest to the stations, respectively, were read off by the telescopes of the instruments.

The angles having been computed between Hospital and Pitch Hill, (or the station visible from both determined to be in line, by "*Raper's Instrument*,) stakes, marked at four feet, were fixed on the profile, all of which were visible from the extremities of the main base. (Rope Walk to Watering Bluff.)

The following then were the angles and zenith distances:—

No.	At Rope Walk. Zero Watering Bluff.			Z. D.	Remarks.	No.	At Watering Bluff.			Z. D.	Remarks.
opp. base.		reading of pole.	eye in feet.				Zero, Rope walk in line Hospital.	eye in feet.	reading of pole.		
1	5° 30′	7.218	4	Z. D.		1	296° 0′ 0″	4	6.756		
2	20.30	9.416				2	- -	- -	8.953		
3	27.00	6.127				3	- -	- -	5.665		
4	40.00	none.	- -	85°. 3′. 50″		4	- -	- -	- -	83°. 06′. 50″	
5	51.30	- -	- -	79.11.50		5	- -	- -	- -	77.38.25	
Hosp.	60.00	- -	- -	77. 0.50		6	Hospital.	- -	- -	76.32.25	
stakes	between do	&Pitch	hill.			stakes	between do.	and	Pitch		
1	64.20	- -	- -	77.52.40		1	300.20.35	- -	- -	78.21.25	
2	70.00	- -	- -	77.51.30		2	304.59.20	- -	- -	79.21.20	
3	76.20	- -	- -	76.22.20		3	309.31.30	- -	- -	79. 5.10	
4	82.40	- -	- -	77.31.20		4	313.40.50	- -	- -	80.45. 0	
5	90.40	- -	- -	79.28.20		5	317.15.45	- -	- -	82.47.40	
Pitch-h	99.15	- -	- -	79.13.00		Pitch	321. 0.00	- -	- -	83. 4.35	
levels	in line	Pitch	hill.			levels	down Pitch-	hill.			
1	- -	- -	- -	80.17.00		1	324.30	- -	- -	84.14.55	
2	- -	- -	- -	83.39.30		2	329.00	- -	- -	86.40.50	
3	- -	5.286				3	335. 0	- -	4.872		
4	- -	10.184				4	341.30	- -	9.770		
5	- -	11.143				5	350.00	- -	10.729		
Height of cliff above sea level 27 feet.						Mean height above sea 26,561.					

Now, it is evident from the materials afforded, and by the principles upon which we have proceeded throughout, that the completion of the diagram of the profile, requires the calculation of the heights and distances, as in Plane Trigonometrical Surveying. The zenith distances, are the means of readings, direct, and reversed. We will, therefore, give merely the outline of reduction, and the whole condensation of results for *protraction* in one table.

Thus, commencing at Watering Bluff; we have, 3rd stake from Pitch = 4.872 − 4 feet, eye = 0.872 dep. − ,024 curv. = ,848 26.561 − ,848 = 25.713 = mean level.

Same from Rope Walk — (No. 3, in line Pitch,) = 5.286 − 4 = 1,286 = dep. 27 − 1.286 = 25.714. The means then, are 25.713, and 25.714.

By zenith distances from Rope Walk. Hospital = 249.99 − 4, eye = 245.99 + 024 curv. = 246.014 + 27 = 273.014 mean height above sea. From Watering Bluff = 249.99 − 4 = 245.99 + 024 = 246.014 + 26.561 = 272.575. Which gives = 272.794 as its mean height.

Such observations are near enough to satisfy any rational mind, when it is considered, that a pinnacle a few feet distant may be a foot above the level thus obtained. Great accuracy, and rapidity of execution, can hardly be expected to go hand in hand. Nevertheless, it is not unfrequently found, that expertness, aided by very indifferent instruments, will be equally accurate with the utmost precaution.

From the foregoing data, the following are obtained, by which four profiles result, containing, with the assistance of the draftsman on the face of the finished plan, all that can be required for such a purpose as we have pre-supposed.

The measured and levelled base, from Rope-walk station to Watering Bluff, is to be protracted thus:—Draw a base line, on which lay off the distances in the formula, adding or subtracting elevations or depressions to 27 feet, (the mean height above the sea,) using the *last* height determined, for the succeeding elevation, or depression given.

Thus, from Rope Walk : zero 27 feet, 1 dist. 100 feet = ,5 (= 6 in.) less than 27. = 26.6, or decimally 26.5; 2 dist. 200 (from zero,) = 26.5 − ,083 = 26.417; 3rd dist. 300 feet = 26.417 + .125 = 26.542, &c., making in all 5 inches depression at Watering Bluff = 26.561.

The next, is the line from Watering Bluff to Hospital, which is on the same principle, but is rendered simpler by the reduction to the tabular form, which affords all the measurements at sight, from the Bluff, round to Rope-walk station.

Station.	Mark.	Reading or Computed.	Height. Eye.	Reduction.	Corr. Curv.	Reduction.	Reduction for Level.	Reduction.	Mean Reductions.	Dist. from 1st point.	Log. of dist. from Rope-walk.	Dist. in feet.
	Stake.		ft.									
At	†1	7.218	4	3.218	—.024	—3.194	—27.0	23.806	23.806	102.33	2.982072	959.56
Rope	†2	9.416	,,	5.416	—.024	5.392	—27.0	21.608	21.608	351.83	2.955664	902.95
Walk.	†3	6.127	,,	2.127	—.024	2.103	—27.0	24.897	24.896	454.06	2.953726	898.93
△	4	79.99	,,	75.99	+.024	76.014	+27.0	103.014	102.792	662.46	2.966756	926.31
△	5	190.29	,,	186.29	+.024	186.314	+27.0	213.314	213.035	867.07	2.998172	995.80
Hosp.	⊙	249.99	,,	245.99	+.024	246.014	+27.0	273.014	272.794	1084.14	3.035086	1084.14
	1	223.544	,,	219.544	+.026	219.570	+27.0	246.570	246.570	91.230	3.017363	1040.80
	2	214.55	,,	210.55	+.024	210.574	+27.0	237.574	237.583	199.590	2.998814	997.27
	3	233.566	,,	229.566	+.022	229.588	+27.0	256.588	256.599	314.425	2.983812	963.41
	4	208.650	,,	204.650	+.021	204.671	+27.0	231.671	231.683	421.745	2.974468	942.90
	5	173.593	,,	169.593	+.021	169.614	+27.0	196.614	196.615	552.985	2.970395	934.10
Pitch.	⊙	179.99	,,	175.990	+.024	176.014	+27.0	203.014	202.802	694.00	2.841354	694.00
	1	140.000	,,	136.000	+.016	136.016	+27.0	163.016	162.783	127.42	2.912582	817.68
	2	74.999	,,	70.999	+.012	71.011	+27.0	98.011	97.809	270.29	2.829182	674.81
	†3	5.286	,,	1.286	..	1.286	—27.0	25.714	25.714	433.82	2.708658	511.28
	†4	10.184	,,	6.184	..	6.184	—27.0	20.816	20.816	586.56	2.554539	358.54
	†5	11.143	,,	7.143	..	7.143	—27.0	19.857	19.857	761.17	2.264657	183.93
									Pitch.	945.1	2.975475	945.1
At	†1	6.755	4	2.755	..	2.755	—26.561	23.806				
Wat.	†2	8.953	,,	4.953	..	4.953	—26.561	21.608				
	†3	5.665	,,	1.665	..	1.665	—26.561	24.896				
	4	80.004	,,	76.004	+.006	76.010	+26.561	102.571				
	5	190.08	,,	186.080	+.016	186.096	+26.561	212.657				
Hosp.	⊙	249.99	,,	245.99	+.024	246.014	+26.561	272.575				
	1	223.980	,,	219.98	+.028	220.008	+26.561	246.569				
	2	215.000	,,	211.000	+.031	277.031	+26.561	237.592				
	3	234.015	,,	230.015	+.035	230.050	+26.561	256.611				
	4	209.096	,,	205.096	+.039	205.135	+26.561	231.696				
	5	174.01	,,	170.01	+.045	170.055	+26.561	196.616				
Pitch.	⊙	179.980	,,	176.980	+.049	176.029	+26.561	202.590				
	1	139.94	,,	135.94	+.049	135.989	+26.561	162.550				
	2	75.0	,,	71.0	+.046	71.046	+26.561	97.607				
	†3	4.872	,,	0.872	—.024	0.848	—26.561	25.713				
	†4	9.770	,,	5.770	—.024	5.746	—26.561	20.815				
	†5	10.729	,,	6.729	—.024	6.705	—26.561	19.856				

Those marked † are determined by reading on poles.

The tenth, and following column, contain the distances and elevations to be projected, for the profile of that portion examined, the elevations, being noted in letters, and the horizontal distances, by figures.

It not unfrequently happens, that the abrupt steepness of the ground, rising immediately from the sea, prevents the measurements on the foregoing system, and that levelling must be conducted solely by the level (or theodolite) on very short distances.

The general works on levelling appear to treat principally on ground not subject to sudden elevations (ascending perhaps to some thousand feet.) A short explanation, therefore, of the methods adopted

in such cases will be given, as well as that of determining the profile, as adapted to engineering operations.

To perform this operation cleverly, two observers and two theodolites should be engaged. Staves of twenty-five feet* should be provided, and the graduated rods securely fastened to them. At the summit, a hole should be bored to insert a T shaped piece of metal. (*Vide* Plate III.) This is to secure the true perpendicular, by attaching two fine lines from the extremities, which are connected at six inches above the heel of the spar, to a hand-lead, and having their distance asunder equal to the diameter of the spar. Now as the battens are on the line of taper, the lead kept *barely* free of the spar, and the sides coinciding with the lines, will be as nearly perpendicular as can be attained. It should be steadied by pikes. If requisite, for very close observation, the sliding rods may easily be adjusted by pulleys, but with telescopes, the distances may easily be read off by the intersection of the wires. Stakes corresponding to the height of the instrument, and length to drive in, should be provided, in order that each station may be available (for measurement at intermediate stations, should they eventually be required for depressions or elevations.) These stakes should be marked, as noted on surveying, viz. by a roll of paper pasted or tied round the head, with a black line at the exact height (*vide* diagram.) Now it is important that the distances should be in a direct line, therefore two observers can proceed more rapidly; but if one only is employed, he must fix on his succeeding station before he quits his last. Thus (*vide* diagram) he commences at the position a, (fixed by eye from zero $= \odot$,) and with his telescope truly level, reads off the height on the measured pole (steadied by two pikes, the pole being placed on a hammered surface or flat stone.) This he notes as in formula, as well as his horizontal distance, by projecting a rod with a plumb-line attached until it plumb the centre of the staff. If a line can be stretched from the points, he can measure, if required, the irregularities; at all events, by eye sketches the profile of that section.† Turning his theodolite round to 180°, or reversing the telescope, he then causes his assistant to place station b, and noting by plumb-line the centre of instrument, and by level telescope its exact height, as well as depression of last station, if seen, he places, if advisable, a stake. Proceeding thus successively, to b, c, d, &c. he finally attains the summit. He now finds that three angles of depression and

* An upper rod of five feet may be made to attach, if required longer.

† The horizontal measurements may be as exactly obtained as required, but are not material beyond the profile

elevation can be obtained, and returning, verifies his line of direction taking away the superfluous stakes. The projection from the angle-book will stand as follows:—

Station.	Eye.	Reading.	Corrected.	Horizontal dist.	Objects seen.	Remarks.
a	4.0	19.0	15.0	20.0	Zero, pole ⊙ 180′*b*	
b	4.0	15.6	11.6	16.0	*a* „ .... „ *c*	
c	3.8	14.8	11.0	19.0	*b* „ .... „ *d*	
d	4.0	19.0	15.0	10.6	*d a* 360 .... „ *e*	dep. taken to *a*.
e	4.1	13.1	9.0	42.0	*d a* 360 .... „ *f*	
f	3.10	23.4	19.6	20.6	*e* ... „ ..... „ *g*	
g	4.2	17.2	13.0	14.0	*f* ... „ ..... „ *h*	
h	4.0	26.0	22.0	15.0	*d*=360 ..... „ *i*	dep. taken to *d*.
i	3.11	9.11	6.0	54.6	*h*	*k not seen*; pole left at *h*.
k	4.0	29.0	25.0	31.0	*h* 360, poles in line.	

Now in reducing this into form, for projection on paper, it is merely necessary to add the succeeding levels to each, and project them from the original base line. The horizontal distances being treated similarly.

Thus, they will stand as in the reduced table of the next example, introduced for practice, the profiles being taken from fancy. The reason for adopting this method is plain, as one direct distance is preferable to a multiplicity of minor measurements.

To project the above, draw a base, fix the extremities, and raise perpendiculars, on which lay off the heights, and draw the parallels. Having the distances, as added together, lay them off on their respective levels, and fill in the profile.

Another method, without spirit level or theodolite, and very frequently practised, is by common square and plumb used by masons, and having one long leg of ten feet.

Assume the inch at ten feet on the diagram, drive a stake at *a*, and by a sliding rod resting at ⊙ raise or depress the perpendicular until the plumb denotes level. The long arm should be graduated, and a plumb-line on a slip of wood made moveable to measure each horizontal distance. When the distances exceed ten feet, a plank is frequently laid on its edge, and the distance measured on it. Further explanation is needless: it is obvious that the base, perpendicular, and rectangle are obtained. This method is frequently used by engineers where a model of the ground with the proposed work, is to be completed.

EXAMPLE II.

The following observations were taken to determine the height of Mount Garnet; let it be required to project the same on paper, and prove the horizontal distance by the angles of depression and elevation observed in the ascent and descent.

Letter & No. level.	Height Eye.	Observed Height.	Horizontal Distance.	Objects seen.	Ang. elev. or dep.	Remarks and Profile of Land.	
	ft. in.	ft.	ft. in.	Zero.			° ′
a No. 1	4. 0	19. 0	14.3	pole ϕ .. *b* 180°		Profile to be inserted at pleasure. Mag.	41. 20
b 2	4. 0	15. 6	11.9	pole *a* .. *c* 180			41. 0
c 3	4. 1	15. 1	15.7	*b* ϕ ..... *d* 180			42. 0
d 4	3. 11	18. 11	6.0	ϕ ...... *e* 180	dep. ϕ 49°. 50′. 40″ elev. *k* 44. 42. 0	coming down.	41. 10
e 5	3. 10	12. 10	15.0	*d* 360* .. *f* 180			41. 0
f 6	4. 2	23. 8	17.0	pole *e*, ϕ, *g* 180	smaller triangles		41. 20
g 7	4. 0	17. 0	16.1	*f* 360 .. *h* 180	omitted, but in		41. 20
h 8	4. 0	26. 0	17.2	*d* 360 .. *i* 180	practice should		42. 0
i 9	3. 8	9. 8	6.0	pole *h* .. *k* 180	be noted.		41. 46
k 10	4. 2	29. 2	25.0	*d* 360 .. *l* 180	*d* dep. 44. 42. 0 *x* elev. 44. 27. 10	taking on descent.	41. 21
l 11	4. 2	22. 8	22.0	*h* 360 .. *m* 180			42. 2
m 12	3. 11	20. 11	19.3	*h* 360 .. *n* 180			41. 37
n 13	3. 11	20. 2	23.0	pole *m* .. *o* 180			41. 51
o 14	4. 2	18. 1	21.6	pole *n* .. *p* 180			41. 24
p 15	4. 0	13. 2	8.0	pole *o* .. *q* 180			41. 30
q 16	4. 2	14. 4	7.0	*m* 360 .. *r* 180			41. 51
r 17	4. 0	15. 0	11.0	*m* 360 .. *s* 180			40. 58
s 18	4. 4	17. 4	11.3	*m* 360 .. *t* 180			40. 55
t 19	3. 2	11. 0	6.0	*m* 360 .. *v* 180			41. 5
v 20	4. 0	16. 0	8.2	*k* 360 .. *x* 180			42. 7
x 21	4. 0	14. 8	5.0	*k* 360	dep. *k* 44. 27. 10		41. 40
Below ϕ	4. 0	..	..	.. ..	elev. *d* 49. 50. 40	Objects for true line of direction, $d=180=$ Shale Bluff .. 84. 21 Stratified Bluff 266. 18	41. 40

* When the stake of a former position is seen, it is noted 360°, or ϕ in combination with the direction of pole, the instrument being adjusted to the two in line.

This is the copy of the rough book. Before commencing on paper it is advisable to reduce the observations to a corrected tabular form, that no chance of mistake may arise. Thus, at first level $= a$. Observed level on staff $= 19, - 4$ height eye, $= 15$, as the true height above the sea level. When the position embraces objects, to which elevations or depressions are taken, the height of the level, + height of eye, must be used in both cases, as the observations are taken to the exact points of the positions of the centres of telescopes, as denoted by *stake*.

Reduction of preceding data to a Tabular form for projection.

Nos. = horizontal; letters = perpendicular.

Station.	Height Eye.	Observed dist.		Diff. Level.	Red. to Sea.	Dist. to be projected		Diff. Levels of telescopes for Zen. Dist., &c.
		Per.	Hor.			Perpend.	Horizon.	
p. level								
a No. 1	4.0	19.0	14. 35	15.000	15.000	15. 00	14.350	Lower stake 4 feet.
b 2	4.0	15.50	11.750	11.500	26.500	26.500	26.000	
c 3	4.083	15.083	15.583	11.000	37.500	37.500	41.583	
d 4	3.916	18.916	6.000	15.000	52.000	52.500	47.583	56.416. + height
e 5	3.833	12.833	15.000	9.000	61.500	61.500	62.583	of instrument above
f 6	4.166	23.666	17.000	19.500	81.000	81.000	79.583	and below for ele-
g 7	4.000	17.000	16.083	13.000	94.000	94.000	95.666	vations and depres-
h 8	4.000	26.000	17.186	22.000	116.000	116.000	112.832	sions.
i 9	3.666	9.666	6.000	6.000	122.000	122.000	118.833	
k 10	4.166	29.666	25.000	25.500	147.500	147.500	143.833	151.666. Same, as
l 11	4.166	22.666	22.000	18.500	166·000	166.000	165.833	the angles of eleva-
m 12	3.916	20.916	19.250	17.000	183.000	183.000	185.083	tion and depression
n 13	3.916	20.166	23.000	16.250	199.250	199.250	208.083	were taken to the
o 14	4.166	18.083	21.500	13.916	213.166	213.166	229.583	marks where the
p 15	4.000	13.166	8.000	9.166	222.333	222.333	237.583	centres of instru-
q 16	4.166	14.333	7.000	10.166	232.500	232.500	244.583	ments stood.
r 17	4.0	15.000	11.000	11.000	243.500	243.500	255.583	
s 18	4.333	17.333	11.250	13.000	256.500	256.500	266.833	
t 19	3.166	11.000	6.000	7.833	264.333	264.333	272.833	
v 20	4.000	16.000	8.166	12.000	276.333	276.333	281.000	
x 21	4.000	14.666	5.000	10.666	287.000	287.000	286.000	291. do.

Too much attention cannot be paid to the *points* of observation, as it is impossible to obtain correct corresponding angles of *elevation and depression,* if the marks for the centres of the instruments be not preserved.

The subject of levelling without surveyors' instruments will be hereafter treated on, under the head of Hints to Travellers.

EVOLUTIONARY SURVEYS.

Having treated on the various points immediately connected with the duties of the surveyor, we now proceed to introduce a few remarks which may not prove unacceptable to those, whose "voices are for war," and endeavour to point out how the pursuit of surveying may be rendered of infinite importance in the conducting of warlike opera-

tions, by fleets, or single ships, as well as rendering the monotonous cruizes of blockading squadrons of some importance, by adding to the store of hydrographic matter.

It may be suggested, this is travelling beyond our bounds. Where knowledge of any kind can be made available to professional pursuits, we do not consider it beyond the surveyor's duty; particularly if such parts of his practice can, in any way, be brought familiarly before those not inclined to quit the beaten track; unless to derive such advantages as we propose to offer. At the same time, it is to be remembered, that there is nothing to exclude the surveyor from his share of action, should he be present. He may, in fact, be called on to perform the important duty of pilot; or, his surveying career terminated, may be selected for a command which may call forth all his energies in the manner of which we are about to treat; when the mind, practised in the details of surveying, arrives at rapid and correct conclusions of distances, and thinks light of difficulties which to others may appear insurmountable. "Knowledge is power;" and the assistance of such a man to a commander-in-chief, of a similar turn, may possibly be turned to important use.

It is proposed, therefore, to show how the surveying details may be carried into execution, either for peaceable or warlike ends, or probably both.

A survey may be conducted with facility by a squadron taking up positions by signals, and taking simultaneous angles; one or two boats being dispatched from each ship to sound out their own triangles, as directed in diagrams for boat's orders.

For instance, let us assume that it is intended to attack two batteries, the ground being unknown, and dangerous, until buoyed. That three frigates and two brigs are to be employed. Let the signal "Take up positions for survey on bearing N. 60° W." imply, that the juniors are to bring the centre and southern frigates on that bearing. Now, it is to be borne in mind, that the attacking vessels are those which will have to make the first *move*, and that the others will remain in position for marks, until they are signalled to move, or are recalled. Let us project it on paper, thus:—On the left side of the paper draw the meridian, N. and S., on which place the senior N., junior frigate centre, second, southern, at three miles (or three inches) asunder. From the centre, project the brigs, N. 60° W. and S. 60° W. each three miles. We thus have, three equilateral triangles. The two brigs will fire in succession, (by signal,) by which two good

bases, by sound, will be obtained between the extreme frigates. Let the batteries be supposed to be East of the frigates, at the extremities of the bases respectively, about three or four miles. Angles taken at the frigates will afford the correct distance, and the boats and brigs will now be at liberty to sound out the space, up to gun-shot; the latter picking up berths about N. 60° E. and S. 60° E. respectively, of the extreme frigates, or in any intermediate positions, which the examination may render convenient, for marks, in the event of its being requisite to haul off at night, (which, in tropical climates, might be calculated on.) Two boats from each vessel would speedily perform the soundings; and should it be necessary to go much within gun-shot, it can be conducted by night. Let each vessel display her distinguishing lights at the foremast. Thus, senior, three perpendicular; next, three horizontal; next, three triangular; next, two perpendicular; next, one. It is evident, in each case, we have one *central* light on the mast. The boats may then conduct their operations as completely as by day, (indeed, the use of lights, for close observation, in surveys is preferable.) Should it be found necessary, buoys could be laid down on the dangers, or measures taken to warp the ships into their positions at night, before the enemy could have an idea of their intention to attack; possibly deeming the dangers of approach sufficient safeguard.

Example II.

Let it be required in a squadron of ten (including small vessels) sailing along an enemy's coast, to perform a rapid survey, the wind being South, and trend of land nearly N. and S.

Let the signal be made, "Form in surveying order, on bearing N. 60° W. in order of sailing in two divisions." The senior would choose his own position, which in this case would be the centre of the northern division. Let us project the figure; draw the meridian, and at about the lower third of the line, draw the line of bearing, = N. 60° W. and S. 60° E., the point *on* the meridian being that of the senior. Let the distance asunder be one mile (on one-inch scale.) Now, the corresponding bearings of the southern line will be, S. one mile, and S. 60° W. on each of the equilaterals. Let the extremes of the southern line fire, to obtain base. Now, supposing that competent persons were only in the ships of the van and rear of southern line, and the chief of northern, the positions, by telegraph, could all

be conveniently fixed. But in these times it is to be hoped many candidates in each would be found. Supposing then, we draw at five miles to the eastward, a fictitious coast-line, with conspicuous peaks; the whole preserving a bearing not much out of the meridian, but wavy. It will be evident, that the leading line shows a base of five miles, and if the astronomical observations are duly made by the chief, the positions of such peaks, points, &c. can be fairly laid down from this base. Now, under such circumstances, provided the vessels be under easy sail, courses up, and all angles taken from the foremasts. the survey could be conducted for any period during daylight; measuring fresh bases at all new conspicuous objects; which, once determined, become effective aids in correcting errors which may arise; as from the fixed positions of two terrestrial points, with one astronomical bearing, the position of the chief would be frequently verified. The soundings being important, such a course must be adopted as will render the track of each ship distinct. Thus, the leading ships bear north, and those westerly N. 30° W., therefore N. 15° W. (or N. b. W.¼W.) would be such a course as would render ten distinct lines of soundings available. Diagrams would have been introduced, but the very object of such dissertations is to induce "*projection from materials*," for this is one of the qualifications most important to the surveyor. If he can only *copy*, or put his *own* work on paper, we must still class him only as an "assistant;" but, if a due energy is exhibited, the learner will, with moderate ability, be entirely independent of assistance.

For this express purpose, then, various examples without diagrams have been introduced; and let it be borne in mind, that until the *first letters* are projected, no idea can be formed of the facility with which the most intricate questions can be illustrated, as it is in the very original construction of the diagrams that the difficulties disappear.

It should be borne in mind, that in conducting such surveys as we have been treating on, two lines are convenient; but one, and advanced frigates or brigs, will be equally good, where it may be of importance to preserve the line of battle or order of sailing.

We will now introduce a case embracing such points, the objects being ships of the enemy.

Let it, therefore, be assumed, as in the diagram* connected, plate X. that five sail of the line and three frigates are chasing an equal force of the enemy.

* As this case embraced signals, and angles applied to a chace, it was deemed necessary to give a plate.

To reduce such an operation completely on paper, so as to ascertain the true positions of every ship opposed, no *doubt* should exist, and unless *previous regulation* has been adopted, would become more complicate than is necessary.

The first question in all such cases is, What do we require? Can it be effected by any two? And which is the simplest mode of conducting it?

As the line of battle is not yet material, and may perhaps depend upon discovery of a weak point in the line of the adversary, the chief has taken the centre. The example, then, will stand thus:—

Example 3.

On 15th June, observed the enemy on the weather beam, about ten miles, made signal to frigates, "Take positions in the wind's-eye (N.N.W.) of the van, centre, and rear respectively;" shifted to centre of line, and showed signal. "Open order, one mile." * Made signal, "Prepare to measure base by sound, on leading and sternmost frigates." At eight, leading frigate's distance by sound 4′,2, sternmost, 2′,85. Showed signal, "Make known principal angles," (numbers, by pendants, to designate friends, letters; by flags, adversaries. Line numbered from van to rear, taken up by leading frigate. The same in adversary's line, *vide* diagram.)

Thus, the rear of the line is required to make known *principal* angles. She will show E. flag at the main, which denotes primary (or right) object, or sternmost of enemy's line; and the flag representing the object taken *to*, over the *degrees*, followed by minutes.

Thus E. A. will be her first *principal* angle. After the chief has collected the principal angles, the remainder will be made on the repetition of the ship's pendant.

On the diagram, it must be evident that all this could be conducted by the principal (chief No. 3) and leading frigate, but the rear of the line affords the means of checking mistakes, a better intersection, and places the positions of the chasing ships, as to the relative rates of sailing with those of the enemy, in a clearer view.

The following, then, would be such a set of angles as would result on the diagram, at the first and second stations, by which the chief is enabled to estimate to the greatest nicety, at what period, provided the wind holds, he may be enabled to *come up with* his adversary; which

* If scales were afforded of the heights of spars, &c., *or marks on lower masts*, the distances for ½, 1, 1½, 2 miles, &c., might be readily computed, and a table for the express purpose kept in each ship.

are his weak points, and what manœuvres will be expedient, in order, by devoting his most efficient and heavy ships on the weakest of their line, to decide the fate of the engagement by a decisive blow. If he can bring superiority in metal, sailing, handling, and efficiency, in opposition to the reverse of these, there can be little doubt of the result; he may be enabled to bring his opponent to action on his own terms, or cut him off in detail.

At 6, A. M. General signal—"Make known principal angles." Pendant No. 6. (Frigate leading.)

Leading frigate's (No. 6) angles.

		° ′
Main No. 1, pend., and	3 pend. over	26. 13
	5 „	39. 7
	8 „	67. 3
	7 „	61. 35
	E flag over	130. 45
	D „	134. 5
Main* E . .	C „	6. 52
	B „	10. 25
(Flag ship)	A „	14. 15
	G „	3 0
	F „	26. 30
	H „	19. 55

Flag ship's (No. 3) angles.

		° ′
5 Main (4 in line) and	8 pend. over	72. 45
	E flag over .	87. 25
	D „	90. 21
	G „	93. 50
	C „	93. 20
	B „	96. 15
(Flag ship)	A „	99. 00
	H „	101. 30
	F „	110. 15
	7 pend. over	113. 5
	6 „	139. 0
6 Main „	1 „	41. 0
„	2 „	41. 10

Second set of angles, at noon.

		° ′
Main No. 1 pend., and	3 pend. over	27. 00
	5 „	41. 50
„ 5 „	8 „	41. 6
	7 „	25. 45
	E flag	81. 30
	D „	83. 40
	C „	86. 5
	B „	88. 45
(Flag ship)	A „	91. 45
	G „	76. 5
	F „	100. 52
	H „	103. 3

Second Set.

		° ′
5 Main . .	8 pend. over	72. 20
	E flag	63. 35
	D „	66. 50
	G „	65. 25
	C „	70. 5
	B „	73. 40
(Flag ship)	A „	77. 15
	H „	86. 0
	F „	91. 0
	7 pend.	112. 33
	6 „	131. 3
6 Main . .	1 „	49. 2
	2 „	49. 28

* Flag used, being sternmost of enemy's line.

Angles (No. 5) rear of line.

			° ′
Main, E flag, and A, flag, over		.	10.50
Principal ∠s	8 pendant over	.	13.50
	7 „		42. 5
	6 „		53. 8
	3 „		81.18
Main, E flag, and D, flag, over		.	2.55
Subsequent	C „		5.40
	G „		7.50
	B „		8.20
	H „		12.15
	F „		22.10

Second Set. *

			° ′
Main, E flag, and A, flag, over		.	15.15
Principal	8 pendant over	.	35.35
	7 „		63.55
	6 „		69. 3
	3 „		102.57
Main, E flag, and D flag, over		.	4. 0
Subsequent	C „		7.30
	G „		5.30
	B „		11.28
	H „		23.10
	F „		30.20

Angles (No. 7) frigate.

		° ′
Main No. 6 pend. and	1 pend. over	77.30
	3 „	119.30
„ 3 „	5 „	27.40
	8 „	74.00
	E flag over	145.20
„ E flag	A „	15.20
	6 pend. over	95.10

Second Set.

Main No. 6 pend.	1 pend. over	91.45
	3 „	135.45
„ 3	5 „	30.50
	8 „	75.41
	E flag over .	113.33
	A „	128.32
„ E flag	6 pend. over	110.42

Angles (No. 8) frigate.

		° ′
Main A, flag, .	6 pend. over	71.16
	1 „	115.12
„ 1 pend. .	3 „	23.38
	5 „	68.48
E flag . .	A flag over	15.30

Second Set.

Main 6 pend. .	1 pend. over	51.18
	3 „	79.50
„ 3 „	5 „	40.10
„ A flag . .	6 „	92.25
„ E „	A flag over	20.50
	6 pend. over	113.15
„ 6 pend. .	7 „	16. 3

The force on the diagram is designated by stripes, thus, Nos. 1 and 3 of the lee line, are three decked, the rest, two.

Remarks, &c.—The ships of the enemy's line, as examined from the flag-ship and chasing frigates, appear to be under an inferiority in sailing and manœuvre, although presenting a more imposing broadside. Thus—the enemy's van, (bearing the flag,) large first-rate, and from canvas and spars must be a very heavy ship; sails fairly, but badly handled, sails not properly set, weather leeches slack, jibs not half up, and sheets too flat in.

No. 2. An eighty-gun ship and heavy, sails badly, badly managed,

and requires all the canvas they can carry, to keep her station ; crank withal.

No. 3. Fair sailer, but not equal to our worst, well handled, sails well set, smart little ship, but only seventy-four.

No. 4. First-rate, heavy, sails very indifferently, infamously managed, not a sail properly set, and lifts all gone; yards droop much, too weak to support canvas; compelled to carry press to keep her station.

No. 5. Fair sailer, works well, in good order, a seventy-four; well rigged, no flying kites. Frigates heavy; headmost, sails better than ours, others inferior.

At 12, measured fresh bases, and found we had gained on enemy.

No. 1. A. of enemy's line, compelled to keep under reduced canvas to keep company, but could not fight her lee lower-deck guns, if pressed.

No. 2. B, falls to leeward of line, sails badly set, cannot keep a good wind, or too fond of hankering her.

No. 3. C, dropping to leeward, and under press of canvas; rate of sailing, one-fourth worse than ours.

No. 4. D, Bags astern withal, but seems to weather her friends.

No. 5. E, weathers, but bears away occasionally to keep her station.

Gain on frigates generally.

From the above dispositions, and knowing, from the following statement of our line, that we are an overmatch in this weather, from our superior order, and very superior sailing, a change was ordered to be effected without disturbing our line, by a manœuvre in tacking, which would make the requisite change in our line of battle to meet the case required, and without permitting the enemy to suspect the object, or that such change, possibly, was more than the effect of accident.

Our line is composed then as follows.

No. 1.—First rate, 120 guns, in very high order, well handled, fine crew, and carries her guns well out of water, sails better than any ship in the enemy's line. Can spare them top-gallant sails. N. B. Moves freely without her courses.

No. 2.—80 guns, sails well, spares us mainsail and top-gallant sails, fine order.

No. 3.—120, (flag,) sails well, well handled, fine crew, but not equal to 1 or 2.

No. 4.—80, sails indifferently, but keeps up with press of canvas; raw crew.

No. 5.—74, small, but admirably officered, crack crew, best sailer, and will "all but speak."

Frigates large, in fine order, and quite equal to cut off their 74, if opportunity offers.

General Signal.—Commander-in-chief intends line of battle to be formed on Numbers 2, van, 7, 3, 4, and 5. No. 1 in tacking will pay off as a feint, and make it appear she is compelled to bear up for 2, (being on the starboard tack.) No. 2 will then tack, and lead, the flag tacking in the wake of No. 2 (in new line.) Signal, "prepare to cut through enemy ahead of No. 4 D," by which our two best ships will be opposed to their worst, and the flag must naturally drop astern to meet his proper opponent, (which would confuse his line, or compel him to sacrifice his sternmost ships.)

Should the enemy tack, they are in the same predicament, as from our known superiority in sailing, we are sure to cut them off, and engage them more at leisure; with a superiority in choosing position, and a confidence which the chase had much increased.

At 6 P.M. Rear of line showed signal, "Enemy's van north-west." Measured base by sound to leading frigate, and found, that allowing the two ships of the van only sailed *as well* as the two rear of adversary, they would exactly meet at the intersection of the dotted lines. But as the rate, is one mile in five gain, by tacking, they will cut off the two sternmost, and be under easy canvas. Should the enemy tack, choice of position offers; when the two leading ships will stay by their opponents D and E, the chief giving his broadside as he passes on to windward, to his opponent; by which the line would be changed into 3, 4, 5, 2, 1. The two first-rates opposed to their equals.

It may be suggested, "We are fighting the action all our own way." We are merely illustrating what has frequently occurred, without having the positive information which science offers. Whether the adversary distances, or nears, forereaches, or drops astern, such will be ascertained. Surveying operations will not draw them nearer, but mathematical precision is preferable to estimated data. The crews are less worked, their spirits are more buoyant, if they know their *ship* has the legs of their adversary. There is no necessity for publishing such

information; it is read in the eye of their captain. When it is considered that many tedious hours are passed in chase, and time hanging on hand, the excuse of the "time it will take to make the necessary signals," cannot surely be advanced against the distinct advantages which result—all could have been confined to Nos. 3 and 6, and the angles to the flag of enemy been sufficient.

Any number of vessels may be included in a survey, as well as any number of boats, provided method be rigidly adhered to, and the whole be under the direction of one head.

Example IV.

Let it be supposed that a fleet of twenty sail of the line, with frigates, brigs, and small vessels in proportion, are required to enter a channel which is not buoyed, or where they have been purposely removed.

One man can conduct the work of this establishment, of 20 stations, and at least 120 boats, and small vessels. Assistants of course he must have, but he may be competent to direct all clearly, should such be required. The first point, is to select commanders of divisions, and to draw out distinct formulæ for their guidance, and upon which their secondary orders must be founded. Every division would have one specific duty to perform; and although acting in concert, still would not in any way interfere with each other; as every boat in the division would carry her vane or distinguishing pendant, until she displayed her "station flag."

The instant a ship anchors, her spare boats perform solely the work of her own triangle, (and without any distinguishing mark which shall interfere with the divisional departments; and the moment a ship finds herself sternmost, she should advance under the *lee* of the line, as every ship would be berthed on the weather side of the channel, her launch forming the triangle (on the lee) between her and her companion astern.

Let us take the river's survey, (Pl. 7,) and call all the objects on the right going up, ships of the line, (until the bend makes it a lee shore,) and the left, their launches. The principal, in his gig, precedes, and places a boat with the yellow blue flag wherever he meets danger; with the general understanding; that white may be *shaved to leeward;* blue *must* be passed to *windward;* red is on the *tip;* yellow blue *less than four fathoms.* Twenty launches, then, have one general order; viz., "take up the position of the first *blue*, on either side in six fathoms, so

as not to be under 50 degrees with the two advanced positions (launch and ship.") Twenty more are assigned to the blue, or lee shore division; to *grope* for the lee side of the channel, and work well over the ground before taking up position, (probably fixed by the principal, as great part will precede him, and perhaps " swarm a shoal.") Twenty belong to the white division, and examine the weather side, under similar regulations. Twenty belong to the red, or "spit boats;" and twenty danger, (yellow blue.) The remaining twenty, sound out their triangles to which their ships belong, aided by other boats, if available. If the boats have preceded the ships a few hours, their stay at anchor will not be an important delay.

The divisions then will be—

1. Division blue, " position finders," on lee side channel.
2. ——— white, ditto weather side.
3. ——— red, "spit boats," on extremities of sands, &c.
4. ——— yellow blue, " danger."
5. ——— blue pierced white, " lee station," (launches.)

Thus then, supposing the lines of the river survey (Pl. 7) to be the margin of the shoals, with the wind at west, the positions of the line-of-battle ships would be—1 B., 2 C., 2 G, 1 C.^{2}, 2 G.^{2}, 1 C.^{3}, *off. crab*, 2 C.^{3}, J.^{3}, 2 C.^{4}, 3 G.^{4}, 2 G.^{4}, 2 C.^{5}, 2 B.^{2}, J.^{5}=14 stations. As the junior would precede, the senior would be at the 20th station. Brigs, and lighter vessels, would complete their lines of soundings: all of which, if conducted by *printed formulæ* could be made available to the surveyor, who, however much excited on such service, could in his calmer moods decypher, at least, the most important parts of such data.

By the constant combination of surveying theory with tactical manœuvres, a habit of estimating the distances from the enemy, as well as *where* each ship in the line may reach her position, is attained; and by signals, the relative position of each ship in adverse fleets may with great facility be placed on paper.

In single ships, (or in fact in every ship,) experiments should be made in determining distances from the base of the ship and spars, which in calms should be very accurately measured. Perhaps, the mould of the bulwark, projection of bowsprit, jib, and flying jib booms, (measured to perpendiculars,) would materially simplify such determinations; and these may fairly be obtained when fitting out, (from the dock-yard.)

Every ship may have a computed table, (to minutes,) arranged, so

that the officer of the watch may, in reporting the proceedings on a beam chase, (within a thousand yards,) be enabled to tell his distance. The trigonometrical formula is simply to be solved thus:—Let two observers take their angles to the objects, from the quarter, and jib or flying-jib boom ends; add the measured angles together, and take their sum from 180°, which equals the angle at the object, which is *opposite the known base.* Then as the log. sine of this angle : is to the base :: so is the log. sine of either of the observed angles : to its opposite side.

If the chace should fire a gun, and the watch be ready at the ear note the beats; multiply them by 456.8, and the result will be the distance in feet:—thus, as the mean rate of good watches is five beats to two seconds, and 1142 feet is the rate of sound in one, one beat equals 456.8 feet. To a person accustomed to measure bases by such means, distances of one mile can be very accurately measured by the mechanical motion of the hand, and it is well worthy the attention of all professional men.*

The annexed table has been calculated on the mean length of a ship of 156 feet on deck, (over all, or from externals of bulwark to quarters,) and 94 to flying boom end; making a base of 250 feet, which is *within the range of frigates.* The distances are first taken on beam measurement, to be effected by affixing marks on the bulwarks, and steering by them during the operation. The second are as far ahead, and as far astern, as the base will fairly work on, and to be guided by corresponding marks on the bulwark.

* It not unfrequently happens, that much anxiety is evinced approaching ports after dark. It has more than once happened, that I have been enabled by the night gun to determine the distance from the flag ship or battery; and it has often occurred to me that light-houses should have guns attached, to be fired at certain intervals; thus affording ships from long cruizes a satisfactory distance, and warning the mariner by the *flash* (seen *much beyond the light*) of the direction of the light, which he would naturally look for at the expected hours. The hours would dispel the *doubt* of the light, as each light-house should have its noted times.

Base. Ship's length and spars.	Direction of object.	Ang. forward.	Ang. aft.	Dist. feet.	Dist. yds.
		° ′ ″	° ′ ″		
250 feet.	Abeam.	88. 0. 0	88. 0. 0	3581	1193.66
		87.36.43	87.36.43	3000	1000.00
		87.30	87.30	2866	955.33
		87.15	87.15	2605	868.33
		87.00	87.00	2389	796.33
		86.45	86.45	2207	735.66
		86.30	86.30	2048	682.66
		86.15	86.15	1911	637.00
		86. 0	86. 0	1792	597.33
		85.45	85.45	1687	562.33
		85.30	85.30	1593	531.00
		85.15	85.15	1510	503.33
		85. 0	85. 0	1435	478.33
		aft or forward.	aft or forward.		
		° ′	° ′		
250 feet.	20° abaft, or	68. 0	108. 0	3323.0	1107.66
	20° before the	67.45	107.45	2949.1	983.03
	Beam	67.30	107.30	2650.1	883.36
		67.15	107.15	2405.4	801.80
		67. 0	107. 0	2201.6	733.86
		66.45	106.45	2029.1	676.36
		66.30	106.30	1881.2	627.06
		66.15	106.15	1753.1	584.36
		66. 0	106. 0	1641.0	547.00
		65.45	105.45	1542.1	514.00
		65.30	105.30	1454.2	484.70
		65.15	105.15	1375.6	458.50
		65. 0	105. 0	1304.8	434.90

By bringing the marks for these terms on; that is, either abeam; 20° before; or, 20° abaft the beam; it can easily be *estimated* under what distance she will fall, as the difference between 67° 45′, and 67° 30′, only gives 100 yards. The principle and computation are too simple for further remark.

We will here introduce an example on a line-of-battle ship, or frigate, thus—

Example V.

Let the length of a line-of-battle ship, or large frigate, be assumed at 200 feet on deck, and 290 feet from flying jib-boom end to quar-

ters (when corrected to the level of the sea.) A base of 290 feet is thus available, and the diagram will convey some idea of the utility of practising this mode of determining the distance from an enemy before shot are thrown away, and velocity lost, by the concussion which the air must receive, from the discharge of guns. The diagram (Pl. IX. fig. 1) has been introduced to explain this. Thus; the larger diagram, A, is at 1200 feet, or 400 yards; the smaller B, =800 yards. Assuming, then, that the first observations were made truly a-beam, (with marks on gangways expressly calculated to meet this problem, and probably fixed by dock-yard.)

Say the angles were, as follows—

At flying jib-boom.	Observer's mark on hat, and battery . .	83° 00′
At starboard quarter.	Battery, and mark on observer's hat . .	83. 00
	Sum =	166. 0
	— 180° = Ang. at Battery	14. 0

Then by plane trigonometry; as, sine 14° ar. co. (or cosec.) : is to base 290 feet, : : so is sine of 83°, : to distance from battery to bow, or quarter, = 1190 feet. As before noticed, each observer should have a white chalk mark, strip of paper, or wood, on the fore part of his hat.

Suppose, that by some mischance, an error of ten minutes had been made, and that the angle forward = 83° 0′; abaft = 83° 10′; battery = 13° 50′; then similar proportion gives 1204 feet, a difference only of 14 feet.

Again, let us assume the angles for the long distance from B.

Say they were, forward 86° 30′, abaft 86° 40′, and battery 6° 50′.

Then, as 6° 50′ : base 290 : : 86° 40′ abaft : to 2433 feet = 811 yards = bow to battery. Allow defective observers the former error of ten minutes, and let the angles be forward = 86° 25′, aft = 86° 35′, battery = 7° 0′.

Then, as 7° 0′ : base 290 : : 86° 35′ aft : 2375 feet = 791.7 yards to battery.

The difference resulting from even such *great* errors, in this long distance, amounts only to 58 feet, = 19,33 yards, (or about the beam of one of our first-rates.

It is to be hoped that the times are now gone by when the intro-

duction of such subjects would have met with opposition, when every thing like innovation would be coldly viewed.

Naval gunnery is now pursued with a zeal which bids fair to render our future engagements more decisive, and it is to be hoped less bloody. The precision of firing, which is now directed to the hull, will cause less shot to be expended; and that "pell-mell" system, by which the crew were the chief sufferers, (not unfrequently without national advantage, or honour to either side,) will be entirely exploded.

If, then, such precision with the great guns becomes a matter of importance, must not the mathematical certainty of the distances be more so? It is often the expressed maxim of the present school, "that not a shot shall be expended before the enemy is within such and such distances." Be it so. But how is it determined, by eye, or estimation? The natural anxiety to return some of the flying messengers of the adversary will, it is too much to be feared, often mislead the judgment. Every ship, then, has the means of estimating to very great precision her point-blank range, and it is to be presumed, that until within 200 yards, there is little chance of any thing like certainty of aim by musketry, (if this is ever to be *regarded* by a man determined on the zealous execution of his duty, or compassing his object.)

If, then, the principles contained in this short treatise, be but moderately practised, we shall in a very short time find persons well qualified in every ship to render important service to the cause; and it should be fully impressed on all, that at such moments, on such occasions, ability, independent of the post of danger, rarely passes without its due reward.

The method and neatness exhibited, in completing and registering such documents, will afford the chief an opportunity of estimating abilities of such nature in his fleet, and should occasion call for an important reconnoitre, it may not perhaps follow, as a matter of course, that the selection should be made from the flag ship. As all such manœuvres would be telegraphed, each captain would employ some duly qualified person to reduce such observations, and (being signed by the party) present them to his chief.

After evolutionary manœuvre, it is a matter of decided practice, that the officers determine the position of their ship at the noon following, from the *log*. Will it be deemed a presumption, if it should be suggested, that the reduction of all such manœuvres to the form of dia-

grams on paper, would materially encourage the practice of the detail of surveying data ?—would afford materials for the encouragement of discussion on *naval tactics*, and thus introduce geometrical investigation into a study, hitherto, almost exclusively confined to the superiors. The *certainties* of each evolution, must then become apparent, and tactics may be made to partake of the amusement of chess. As before observed, "knowledge is power," and we well know, that on *professional* ability alone, our chiefs have risked the fate of fleets under very great inferiority of force.

Professional knowledge is not the only requisite in these times. The service does not admit of long employment, and society looks to the man belonging to a scientific profession, for a fair acquaintance with other subjects which may render him an acquisition to the circle in which he may be thrown ; and it is his duty, at such times, to take advantage of the "lull," to complete the course of study which his early entry in the service has interfered with.

It is yet more important with the surveyor : he is selected for the command of voyages of examination or of discovery. The country is put to great expense in providing him with every requisite for the pursuit of science, in all its branches ; and it is a reflection on government, and himself more particularly, if any subject is left incomplete. Under such circumstances, the commander is naturally contrasted with those of other nations ; and it is much to be regretted, that we have not such a system of education in this country, as will place us on an equality with our neighbours.

If ten candidates were educated for this special service, and distributed in our ships, the advantages would very soon become apparent. Permit their entry at fifteen, and providing masters at *their expense*, let them be taught mathematics, astronomy, natural philosophy, and languages ; (a fair knowledge of history, French, and classics being a requisite for admission.) The officer having charge of them to be sent to examine foreign ports, to facilitate the acquirement of the languages, mix with men of science, and (not the least important) combine their sea and mathematical duties, so as to prevent their acquiring a distaste for their own profession. Such men to be required to produce as their passing requisites,—the complete surveys of the ports visited—remarks embracing every subject connected with the duties of surveyor, engineer, practical gunnery, and professional subjects, as well as natural history. In return for such acquirements, a certain number might receive commissions ; but no new entries permitted, beyond the

number; the pay, on the same footing as engineers of the line, without extra allowance when specially employed. The surveyor, who risks his constitution,—and where is the man who has not suffered?—might then hope for a retirement, which in the event of sickness might support him. Having touched on this subject, we will endeavour to lead the young surveyor to the study of such points as may be ultimately expected from him when he may arrive at a command; and although not forming part of our required education, ought nevertheless to occupy his mind. The name of natural philosophy should not startle him. The every day occurrences are but part, and half the tricks of his boyhood are founded upon it. It is not *necessary* that he dive deep into it, but he ought to understand, at least, the law by which his ship is borne on the surface of the sea. Should government intrust one of his Majesty's ships to his keeping, and send her on dangerous service, he should be prepared—he should feel a *pride* that all his *plans* for the preservation of his ship, stores, and crew, are *complete*. Should opportunity place him in a situation to become the agent in forwarding science, he should be prepared so to collect, register, or experiment, that others may not be able to say, "Pity a more experienced man had not been sent." Let him not flinch at this. It requires but *common ability*, added to *determination to do his best*.

Various examples will therefore be introduced, on such subjects as the professional, or surveying, duties may not unfrequently call for, and which should equally form part of the education of an officer. The nature of the service, is one which leads to constant invention, and this cannot be better aided, than by having at command some of the means by which correct conclusions can be drawn.

It should be part of the duty of every officer to determine the capacity of the ship he serves in, the weights on board under their respective classification, and, not the least important, what convenient stowage the boats afford—first freed from crew—the weight of men being known—fully laden in tow—laden to pulling mark—also to provision, and extras, for ten days. The weight of cordage she can conveniently take; and knowing its weight, with that of the anchor, the man, who possesses such knowledge, can instantly determine what ought to be effected by his boats under any circumstances. The rescinding an order, because the boat *cannot carry*, particularly after an inferior has stated so, is thus avoided, and perhaps time and life saved. The arguments which could be adduced are too numerous to be dwelt on. We will merely close by offering a few useful rules, which have been

copied from various authors; and hope that a volume of such, on a more extended scale, may ere long be introduced by those who are equally interested in the character of the profession, and better qualified to impart such knowledge from original talent.

The tonnage, then, will occupy the first place.

As all old formulæ should be retained, in order to compare or determine the relative value, they will be given first.

Rule. (Act of Parliament.)—Multiply the length of keel for tonnage by the extreme breadth, the product again by the half breadth, and divide by 94.

Thus:—His Majesty's ship, Caledonia (before alteration) keel, 170 ft. 11 in.=170,91; breadth, 53 ft. 6 in.=53,5.

Then, $170{,}91 \times 53{,}5 = 91436.85 \times \frac{53.5}{2} = 244593{,}57375 \div 94$ $=2602$ tons.

Conqueror, 74; keel, 144 ft. 3 in. = 144,25; beam, 49.0.

$144{,}25 \times 49 = 706825 \times \frac{49}{2} = 173172.125 \div 94 = 1842\,\frac{24}{94}$ tons.

This is simpler by logarithms. To the log. of the keel for tonnage add the logarithms of the beam and half-beam, from which subtract the log. of 94, or add its ar. comp.

Thus, in his Majesty's ship Caledonia—

Log. keel	170.91	2.232767
„ Beam ..	53. 5	1.728354
„ ½ beam ..	26.75	1.427324
Ar. comp. 94		8.026872
	2602,06	3.415317

De Chapman, the Swedish architect, mentions another method, but which requires a reduction to English measure.

Rule.—Take the length from the outside of the stem to that of sternpost. Main breadth outside of wales, depth of hold from midship to *keel.* Multiply the three together, and divide by 100, or cut off the two right-hand figures, the quotient will equal the burthen in tons of 2,000 lbs.,* or 42 cubic feet of articles.

The law relating to tonnage has not yet been changed, but the following has been proposed, by the committee ordered to report on the subject, as that which will induce improvement in build, as regards the merchant service.

* 240 lbs. less than a ton.

1. Divide the length of the upper deck, between the after-part of the stem and the fore-part of the sternpost, into six equal parts.

2. At the foremost, the middle, and the aftermost of these points of division, measure in feet and decimals the depths from the under-side of the upper deck to the ceiling, at the limber strake. In the case of a break in the upper deck, the depths are to be measured from a line stretched in continuation of the deck.

3. Divide each of these three depths into five equal parts, and measure the inside breadths at the following points, viz., at one-fifth, and at four-fifths, from the upper deck, of the foremost and after-most depths; and at two-fifths, and four-fifths, of the midship depth.

4. At half the midship depth, measure the length of the vessel, from the after-part of the stem to the fore-part of the sternpost.

5. Then, to twice the midship depth, add the foremost and the aftermost depths, for the *sum of the depths.*

6. Add together the upper and lower breadths at the foremost division; three times the upper breadth, and the lower breadth at the midship division; and the upper, and twice the lower breadth at the after division, for the *sum of the breadths.*

7. Then multiply the sum of the depths by the sum of the breadths, and this product by the length, and divide the final product by 3500, which will give the number of tons for register.

8. If the vessel have a poop, or half-deck, or a break in the upper deck, measure the inside mean length, breadth, and height of such part thereof as may be included within the bulk-head. Multiply these three measures together, and dividing the product by 92,4, the quotient will be the number of tons to be added to the result, as before found.

9. In order to ascertain the tonnage of open vessels, the depths are to be measured from the upper edge of the upper strake.

10. If it be required to find the real capacity of a vessel, multiply the total register tonnage by 92,4, which will give the contents in cubic feet.

EXAMPLE.

Ship Dunira.

Length at half midship depth	159. 4		
Depth at foremost division	29.66	..	29.66
" midship do.	30.66	×2=	61.32
" aftermost	29.08	..	29.08
Sum of depths			120.06

Breadth at foremost division.			
,, at one-fifth of the depth	37.74	..	37.74
,, at four-fifths do.	31.00	..	31.00
Breadth at midship division.			
,, at two-fifths of the depth	40.00	×3=	120.00
,, at four-fifths of do.	36.08	..	36.08
Breadth at aftermost division.			
,, at one-fifth of the depth	34.58	..	34.58
,, at four-fifths of do.	17.50	×2=	35.00
Sum of the breadths			294.40

Then $\frac{294.4 \times 120.06 \times 159.4}{3500} = 1609$ register tons.

Then $\frac{39 \times 30 \times 6.5}{93} = 82$

Mean $\left\{\begin{array}{l}\text{Length .. } 39\\ \text{Breadth . } 30\\ \text{Height .. } 6.5\end{array}\right\}$ of poop.

1609 as above.

Total Register .... 1691 for Dunira.

For real capacity, $1691 \times 92.4 = 156{,}248$ cubic feet.

It is frequently desirable to ascertain the length and diameter of ships spars, particularly those in his Majesty's service, but as the build differs, so must the masts. It certainly would be satisfactory to a commander having lost a spar, if he could distinctly ascertain whether one to meet his wants could be expected from a ship in sight, but which it might be inconvenient to wait for, if this question could be solved by rule.

The old rule for mainmast was, multiply the extreme breadth by 2,356, to the result add one inch for every three feet. This gives a

fair approximation, (as tried in 1824, by myself.) The diameter is equal to one inch for every yard in length.

A work, containing all information of this nature, and which should be supplied every captain who takes an interest in such calculations, has been published by Mr. Edye, but it is to be regretted that no precise rules for the determinations accompany it; the reader must refer to it for details; a few extracts only have been made, as applicable to the surveyor.* Ever in danger of losing or grounding his vessel, his mind cannot be too much alive to the preservation of his stores and provisions, should it be deemed necessary to put them overboard. Upon the capability of his spars for such purposes, experiment then comes too late to assist him; it is, therefore, one part of his duty to provide for every emergency in which he may be placed, *before* he puts his ship over doubtful ground.

A very few words on this subject will point out how simply he is to effect this. Before sailing, he will of course supply himself from the dock-yard with the dimensions of his spars, and their weights. Thus, let us take the spars of a brig of 386 tons. Spare topmast weighs 10 cwt. 2 qrs. 6 lbs. = 1182 lbs. Now, the specific gravity of pine = ,550, or Riga may safely be assumed at ,666, or one-third less than water; therefore one-third of 1182 lbs. = 394 lbs., and the body being immersed, will be surely provided for, on the principle set forth under the head of Specific Gravity, (that it loses a quantity equal to the weight of its own bulk of water.) We next refer to some body which we require to be preserved, and knowing its cubic contents, it is simply adding the corresponding weight of water, which is equal to the cubic contents in feet, multiplied by 62,5, (which is the value of a cubic foot of fresh water, as compared to the specific gravity of other bodies. The cubic foot of salt, which would be the true value to be used in experiment, is 64,4.)

As the weight of the spars is given, with the iron included, the greatest certainty may be attached to the proportion which has been assumed; as two-thirds, or ,666, is very nearly the mean of other denser woods, including elm. In making use of tanks, casks, &c., the internal capacity is immediately attained by multiplying the gallons by 10; and subtracting the weight of the tank, will give the floating power. One cubic foot is equal to 6,25 gallons, and each gallon = 277.274 cubic inches.

Thus, let it be required to determine the floating power to be

* They are denoted by the mark †.

obtained from a four-feet tank.* The internal capacity is equal to 60 cubic feet, which is equal to 33 cwt. 2 qrs. 3 lbs. The weight of the tank itself is 7 cwt., which subtracted from 33 cwt. 2 qrs. 3 lbs. leaves 26 cwt. 2 qrs. 3 lbs., which weight it will *safely bear up*, if used for a raft, or will carry something in iron under water, about one-eighth heavier = 3 cwt. 1 qr. 7 lbs. + 26 cwt. 2 qrs. 3 lbs. = 29 cwt. 3 qrs. 10 lbs. = 12 pr. long gun; thus relieving the vessel, by such a disposition; of water, 33 cwt. 2 qrs. 3 lbs. + weight of tank = 7 cwt. + gun = 29 cwt. 2 qrs. = 70 cwt. 0 qrs. 3 lbs. = $3\frac{1}{2}$ tons. The fresh water would of course go into casks, as the lids of tanks are not sufficiently tight for this purpose.

SPECIFIC GRAVITY.

In order to draw correct conclusions in experimental research, the principles of natural philosophy should first be mastered; but as it does not of necessity, in the present state of our profession, enter into the education of a naval officer, we must be content by rendering all explanations, which affect such principles, as clear as the nature of the science will admit. If a piece of wood be thrown into the water we perceive that it floats, and we say such a wood, or its bark, as cork, is "buoyant." The cause of this buoyancy, is the relative difference in weight between the fluid by which it is supported, and the body itself. Thus, suppose we take a globe of fir, three inches diameter, and place it in coloured water, so as to leave a mark at its line of immersion. This would show the relative degree of buoyancy between the wood and that fluid. Now, add as much common salt as the water will dissolve, and colour it still deeper. On placing the globe* in it, the water-line, or mark of immersion, will be found considerably less, and the wood float higher, or be more buoyant. Wash the wood in warm water, dry it, and to boiling water add as much alum as it will take up; the ball will be still more buoyant, and why we will proceed to show.

* I have not found the tanks run so large on internal measurement, as to *contents*, as Mr. Edye represents, possibly from the many coats of whitewash; if 47 inches be taken as the internal cube, it will be found very nearly to meet experiment.

† This globe should have a known weight stuck on one side, to cause it to swim evenly in each fluid.

Fill a tumbler with pure water, so that no more can be added without causing it to overflow, placing it previously in a glass (ice) plate. Weigh the tumbler, globe, and glass plate accurately, before putting the tumbler into the latter. Cautiously (by a silk) ease the globe into the water, and when it has had its full effect in displacing the water in the tumbler, as cautiously lift it out, and allow the drops to fall into the tumbler. Carefully remove the tumbler, and by weighing the plate and its contents, they will give the weight of water and plate, from which subtract the weight of the plate, and the result should be, exactly the weight of the globe, because it only "displaces its own weight of the fluid in which it is immersed." If a glass graduated measure, or a narrow phial be at hand, note the space the fluid from the plate occupies. Dry the plate, tumbler, and globe, and use the salt and water in the second experiment. The globe will not displace so much as with the common water, as it does not immerse so deep, and therefore the fluid displaced must, as in the previous experiment, equal the weight of the globe, and measure less when put into the same measure or phial that the water occupied, consequently the fluid must be heavier, as much heavier as the dose of salt added to it. The third fluid will occupy still less space, (because cold water takes up nearly as much salt as hot, and crystals are formed at the boiling point, but alum is more readily soluble in hot water.) This difference then between bodies is their specific gravity, and is referred to distilled water, as 1000. Any body, then, having a specific gravity exceeding 1000, is heavier than distilled water, and will not float on it; bodies having a less number to denote their specific gravity, lighter, and will float. This may be carried to the metals in their fluid state, natural or by heat, and a lighter metal will therefore float on the surface of that of greater density, as iron on mercury, &c. or molten lead.

To determine the specific gravity of a body, it is first weighed in air, then in water. In the latter case, it loses a quantity precisely equal to the weight of its own bulk of water. It is obvious, therefore, that if the whole weight, be divided by the loss of weight in water, the result will equal the specific gravity.

When the body is heavier than water.

Weigh it, both in, and out of water, and take the difference, which is equal to the weight lost in water.

Then, as the weight lost in water, is to the whole weight, so is the

specific gravity of water = 1000, to the specific gravity of the body.

When the body is lighter than water; annex to it a piece of another body, so that the two may *sink*. Weigh the denser and compound masses separately, in and out of water, and find how much each loses in water, (by subtracting its weight in water from that in air,) and subtract the less of these remainders from the greater. Then,

As the last remainder : weight of light body in air : : specific gravity water = 1000 : spec. grav. of the body.

For a fluid.—Take a piece of a body of a known specific gravity, weigh it, in and out of water, finding the loss of weight by taking the difference of the two; then, as the whole or absolute weight : loss of weight : : specific gravity of solid : specific gravity of fluid.

To determine the quantities of two ingredients in a given compound.

Take the three differences of every pair of the three specific gravities; namely, the specific gravity of the compound, and each ingredient, and multiply each specific gravity by the difference of the other two: then,

As the greatest product : to the weight of the compound : : one of the other products : the proportion required.

Ex. A composition of bell-metal, weighing 112 lbs., gave a spec. grav. of 8784.

Spec. grav. of copper being taken at 9000, and tin at 7320.

$9000 - 8784 = 216$. $9000 - 7320 = 1680$. $8784 - 7320 = 1464$. then $216 = \alpha$ $\quad 9000\ a$

$1680 = \beta \quad 8784\ b$

$\alpha \times \gamma = \alpha\gamma \qquad \beta \times x = \beta x \qquad y \times \alpha = \alpha y \qquad 1464 = \gamma \quad 7320\ c$

$112 w$

x and y required.

$$\left.\begin{array}{l} \text{As } \beta x : w :: \alpha\gamma : \text{weight of copper} = 100 \\ \text{As } \beta x : w :: \alpha y : \text{weight of tin} = 12 \end{array}\right\} 112$$

To determine the magnitude of any body from its weight.

As the spec. grav. : to its weight in ounces : : 1 cubic foot : its content; in cubic feet or inches.

To determine the weight from the magnitude.

As 1 cubic foot, or 1728 cubic inches : content : : its tabular specific gravity : weight.

$$\left.\begin{array}{r} \text{Spec. grav. air} \ldots\ldots = 1.201 \\ \text{Water} \ldots = 1000 \\ \text{Mercury} \ldots = 13592 \end{array}\right\} \begin{array}{l} \text{When bar.} \ldots 29^\circ\ 5'; \\ \text{Therm.} \ldots 55 \quad . \\ \end{array} \begin{array}{l} \text{or, air} \ldots 1.222 \\ \text{water} \ldots 1000 \\ \text{Mer.} \ldots 13.600 \end{array}\left.\right\} \begin{array}{l} \text{Bar. } 30^\circ \\ \\ \text{Ther. } 55^\circ \end{array}$$

Which = mean height in England.

In determining the weights of shot, &c. the following, although not to extreme nicety, will meet all that can be looked for in practice, as connected with professional objects.

The calibre of guns, is equal to the diameter of the shot plus 1-49th the diameter of the shot, (= windage.)

In order to determine the weight of a shot from its diameter, which is nearly equal to one-third of its girth, the weight of a standard shot has been determined; viz. a shot of 9 lbs. = 4 in. diam. (which has been assumed as the most convenient, being free from decimal proportions.)

Rule.—Multiply the log. of the diameter by 3 (= cube), and add the constant log. 9.148063, the result equals the weight.

To determine the diameter from the weight.

Multiply the weight by 7,111, the cube root of the product equals the diameter. Or, to the log. of the weight, add log. 0.851937, divide the product by 3, the quotient = the diameter.

To determine the weight of a leaden ball.

A ball of lead, of one inch in diameter, equals 3-14ths of a lb.; therefore, reducing 3-14ths to a decimal = ,2143. To the log. of the diameter, multiplied by 3, add the constant log. 9. 331022, the result equals the weight.

In the field, (where no logarithms are at hand:) as the cube of the known ball = 1 inch : its diameter ,2143 :: the cube of the diameter of any other given ball : the weight.

In reducing the diameter from the weight.

To the log. of the weight, add the const. log. 0. 668978 = ar. comp. of ,2143, and divide the sum by 3, the result equals the diameter.

To determine the weight of a shell.

From the cube of the external, subtract the cube of the internal diameter; multiply the remainder by 9, and divide the product by 64 = weight.. Or, to the logarithm of the difference of cubes, add the constant log. 9. 148063, the result equals the log. of the weight.

It frequently occurs that shells are filled with lead; therefore, in order to determine their weights when thus treated, it is merely necessary to take the internal diameter and determine its weight as a

spherical body of lead, to be added to the weight of iron, as deduced from the preceding.

In order to form correct estimates of the shot used by an enemy, and whether the ordnance from which they were fired will be available, if captured, it is necessary to take into consideration the amount of windage, and the general diameters of shot of other nations. It is to be feared we are treading almost too close upon gunnery by introducing these subjects; but as the duties of engineer should be combined with those of surveyor, it must serve as our apology. From various papers, collected during the last twenty years, a small table will be formed, which, at sight, will enable those interested in these matters, to determine whether the shot of the enemy comes from foreign or British ordnance, and to draw such conclusions as our remarks have been chiefly intended to excite.

The following was the windage for British guns:—

Long.	68 Prs.	42	32	24	18	12	9	6	4	3	2	1
	,34	,33	,30	,27	,25	,22	,20	,17	,15	,14	,12	;09
Carr.	,15	,15	,15	,14	,12	,12						

Mortars and howitzers, 13 to $5\frac{1}{2}$ = ,15 ; $4\frac{2}{5}$ = ,2.

French guns all one line, 68 pr. $\frac{1}{50}$, siege guns $1\frac{1}{2}$; 24 pr. $\frac{1}{48}$; mortars 13 = 4 ; 10 = 1 ; 8=1 ; howitzers 2.

Long Guns.				Iron.		Brass.		French.		Spanish.		Dutch.		Portuguese.		Russian.	
Prs.	Calibre.	Dia. Shot.	Weight Lead.	Length	Weight.	Length.	Weight.	Dia. Shot.	Weight Shot.	Dia.	Weight.	Dia.	Weight.	Dia.	Weight.	Dia.	Weight.
68	8.0080	7.8480	103.20														
42	6.8208	6.6844	63.88	9.6	67.0. 0	16.6	66.0. 0	....	....	....	....	....	....	7.49	59.09	6.860	45.40
32	6.2297	6.1051	48.65	9.6	55.0. 0	10.0	55.2. 0	6.3496	36.00	6.840	45. 0	6.400	36.87	6.800	35.12	6.470	38.08
24	5.6601	5.5469	36.44	9.0	47.2. 0	9.6	53.0. 9	5.808	27.55	6.030	30.84	5.920	29.18	5.930	29.32	6.000	30.38
18	5.1425	5.0397	27.43	9.0	40.0. 0	5.9	18.0. 0	5.074	18.37	5.520	23.65	5.450	22.77	5.400	22.14	5.450	22.77
12	4.4924	4.4026	18.25	9.0	32.0. 0	9.0	31.2. 8	4.610	13.78	4.800	15.55	4.760	15.16	4.700	14.60	4.760	15.16
						6.6	18.0. 0										
9	4.0816	4.000	13.71	7.0	23.0. 0	....	....	4.027	9.18	4.200	10.42	4.130	9.90	4.300	11.18	4.170	10.20
6	3.5656	3.4943	9.109	8.0	22.0. 0	6.0	8.3.27	....	....	....	....	3.780	7.60	3.750	7.42	3.780	7.60
				6.0	16.2. 0												
4	3.1149	3.0526	6.080	6.0	22.1. 0	....	....	3.196	4.59								
3	2.8301	2.7734	4.552	4.6	7.1. 0	3.6	2.2.27										
2	2.4723	2.4228	3.037	....	....	....	3.1. 0										
1	1.9622	1.9230	1.517														
in.			filled.														
13	13.000	12.783	349.19	5.3	82.1. 0	5.3	82.0. 8										
Land	13.000	12.783	349.19	3.7½	36.2.12	3.7½	25.0.10										
10	10.000	9.833	158.958	4.8	41.0. 0	4.8	33.0. 0										
Land	....	....	....	2.9	16.0. 6	2.9	10.1.25										
8	8.000	7.867	81.407	2.1¾	8.0.10	2.1¾	4.1. 8										
*6½	5.800	5.703	31.009														

* Guns.

The officer whose mind is constantly devoted to professional studies has a decided superiority over those around him; he is ever on the alert, and is enabled to conduct his duties with an energy and alacrity which inspires confidence in those *under his command*, and thus materially assists their physical force—for *will* is an increase of power. His countenance never betrays that dangerous symptom, *sullen doubt*, especially in the presence of *his superior;* the word impossible is not to be found in his vocabulary. We will proceed to show how the knowledge we have alluded to, and more particularly *specific gravity*, is intimately connected with the duties of a naval officer. For instance, he is at anchor in a river. He knows what burthens his boats will carry on fresh water, and what difficulties rough sea will then produce. He can readily foresee the advantages which will arise the instant they get into salt water; he can estimate their difference of buoyancy in his mind, and at the moment, perhaps, another of less thought had given it up as hopeless, he succeeds in his object.* Iron work is to be carried. He knows the burthen his boats can carry *in them*, and he can readily estimate the decrease of weight which would result from slinging the same under water. From the known specific gravity, or displacement of water, he can estimate how far his means will admit of buoying provisions through a surf, which *boats' crews alone* could attempt. He ascertains, from the difference of specific gravity, how far his casks will float, and what quantity they should be short of *contents* to enable them to tow buoyantly; for it is frequently a mistaken notion, that water-casks, filled with fresh water, will not sink. [It has been repeatedly proved, that filled with salt water, and bungs out, they will.] Should the casks have been long subject to exposure, and been much rolled on the beach, the weight of hoop, and being water-logged, carries them down.

No dependence then should be placed on the barécas with which boats are furnished, unless they are not quite full.

The power of casks, tanks, &c., in floating the ship,' guns, provisions, &c., can be duly estimated; and, probably, it may be a matter well worthy of the consideration of a commander, if he only started one-fourth of his water, and attaching some light provision-cask to the lid of the tank, let all his provision, &c., be thus moored in a place of safety, until the ship could be got off.† In smooth

* It is not to be imagined that any great advantage, in point of immersion, is to be gained, because the difference cannot exceed 28 lbs. in 1000. The *activity* and *buoyancy* is *sensibly* felt notwithstanding. A cubic foot of salt water is heavier than that of fresh, by about 2 lbs. The difference of flotation in a first-rate $=5\frac{3}{4}$ inches, between river and sea water

† In doing this he must secure the tank-lids by *dough* and old canvas. Flour made int

water, this might frequently be performed, and much subsequent anxiety and distress saved. In forming rafts, all heavy bodies which can be slung under water should be so disposed; flour will not injure.

The following Table of Specific Gravities has been compiled from the works of various authors on chemistry, and wherever they have been found to differ, the results have been repeated. For all purposes connected with professional inquiry, they will be found more than adequate; if closer investigation is intended, the reader must refer to the works of Henry, Dalton, Ure, Thompson, Brande, &c. "Who shall decide when doctors disagree?"

Table of Specific Gravities of bodies, taking distilled water at 1000.

Body.	Sp.Gr.	Body.	Sp. Gr.	Body.	Sp. Gr.	Body.	Sp. Gr.
Platina pure	23000	Glass	32 03	Sea-water	1028	Cows' milk	1032
	20722		3150	Oak (heart)	1170	Human do.	1020
Gold*	19400	Green	2732		925	Urine	1010
	19362		2600	Ice	930	Burgundy	991
Standard	17724	Flint	2594	Ebony	1209	Champagne	962
	17629		2570	Mahogany	1063	Brandy	837
Mercury (pure)	14000	Granite	3500	Olive	927	Alcohol	829
	13600	Common stones	2520	Mulberry	897	Nitric ether	909
	13598	Limestone	2950	Beech	852	Acetic ether	866
Lead (common)	11325	Basalt	2860	Yew (Spanish)	807	Sulphuric do.	739
	11352	Marble 2837 to	2668	Apple	793	Muriatic	729
	11350	Chalk	2780	Plum	785	Oil cinnamon	1044
Fine silver	11091	Jasper	2710	Cherry	715	Cloves	1036
Standard†	10535	Quartz	2600	Quince & orange	705	Lavender	894
Palladium	11300	to	2800	Walnut	671	Sp. turpentine	870
Rhodium	11000	Coral	2680	Pear	661	Linseed oil	940
Bismuth	9850	Slate	2640	W. Sp. Poplar	529	Poppy	929
Copper	9000	Clay	2160	Cypress	598	Almond	917
Coins	8915	Earth	2000	Cedar	561	Olive	915
Wire	8878		1984	Fir	550	Spermaceti	943
Gun metal	8784	Brick	2000	Cork	240	Butter	942
Cast brass	8000	Nitre	1900	Phosphorus	1714	Tallow	941
Wire	8544		1936	Amber	1078	Mutton suet	923
Molybdena	8611	Ivory	1825	Camphor	988	Hog's lard	957
Arsenic	8308	to	1917	Sulp. acid	1850	Bees' wax	965
Nickel	8279	Sulphur	1991	to	1970	Gum Arabic	1452
Uranium	8100		1810	and	2125	Tragacanth	1316
to	9000	Gunp. compact.	1745	Nitric acid	1554	White resin	1082
Steel	7850	Alum	1720	Muriatic	1259	Mastich	1074
to	7760	Sand	1520	Corr. acetic	1062	Copal	1045
Cobalt	8610	Pit-coal	1329	Madeira	1038	Opium	1337
Iron	7645	to	1250	Cyder	1018	Amber	1065
Cast	7425	Boxwood	1328	Brown beer	1033	to	1000
Tin	7320	0,912 to	1030	Asses' milk	1035		
	7291						

dough balls will reach distressed persons, and not be damaged by the water, and if dry flour be within, it is safe.

* Legal standard = 22 carats. = 22 gold, added to 2 alloy; *mark*, standard 18.

† Legal standard 11.2 silver, added to 18 dwts. alloy; marks, standard, new sterling Brittania, and Lion's Head, King's Head added when duty paid; Godsmith's Office, Leopard's Head; Dublin, Harp; Edinburgh, Thistle; Newcastle, Three Castles; Sheffield, Crown; Birmingham anchor.

The following Tables afford the means of determining what are the floating powers at command; and what number of gallons will be required to support the heavier bodies.

Object.	Galls.	Weight Empty.	Weight of Contents.	Length.	Diameter.	Breadth.	Cubic feet.	Buoyancy.	In pounds.	In gallons.
		cwt.qr. lbs.	cwt.qr. lbs.	in.	in.	in.				
Leager	159	2. 3.23	14. 0.24	59	38	..	25.44	20.18	1261	126.1
Butt.	110	1. 2. 9	9. 3.10	53	33	..	17.60	14.80	925	92.5
Puncheon	73	1. 0.14	6. 2. 7	41½	30	..	11.68	9.74	609	60.9
Hogshead	55	0. 3.12	4. 3.19	37	28	..	8.80	7.28	455	45.5
Barrel	36¾	0. 2.16	3. 1. 3	31.5	22	..	5.88	4.72	295	29.5
Half-hogshead	27½	0. 2. 3	2. 1.23	28	20	..	4.40	3.29	216	21.6
Tank	387	7. 0. 0	34. 2.20	48	48	48	61.92	49.60	3100	310.0
Half do.	189	3. 2. 0	16. 3.23	38	38	38	30.02	24.11	1507	150.7
Quarter do.	93½	2. 0.24	8. 1.15	38	38	19	14.96	11.05	691	69.1
Bilge do.	108¼	2. 2.20	9. 2.23	38	33	28	17.32	12.60	787	78.7
Bread-bag	112lbs.	0. 0. 2	1. 0. 0				lbs.	total.	Buoy	ancy.
Beef barrel	28	0. 1.14	1. 3.22	28	21	..	280	300	— 20	2.0
Pork	26	0. 1.14	1. 3.22	27	21	..	260	300	— 40	4.0
Flour hogshead	54	0. 3.12	5. 0. 0	36	28	..	540	656	—116	11.6
Half do	28	0. 1.17	2. 2. 0	37	22	..	280	325	— 45	4.5
Barrel	36	0. 1.24	3. 0.24	30	24	..	360	412	— 52	5.2
Suet barrel	36	0. 1.24	2. 2. 0	30	24	..	360	400	— 40	4.0
Sugar hogshead	63	0. 3.26	5. 0. 0	35	28	..	630	670	— 40	4.0
Half do.	28	0. 2.10	2. 1. 8	28	22	..	280	326	— 46	4.6
Barrel	36	0. 3. 3	3. 1. 8	30	25	..	360	459	— 99	9.9
Cocoa barrel.	36	0. 1.24	2. 0. 0	30	24	..	360	276	+ 84	8.4
Tobacco	28	0. 1.17	0. 2.26	26	23	..	280	127	+153	15.3
Pease, hogshead	60	0. 3.12	4. 1.25	36	30	..	600	597	+ 3	0.3
Barrel	40	0. 2.20	2. 3.26	32	24	..	400	410	— 10	1.0
Half-hogsh.	28	0. 1.17	2. 0.10	27	23	..	280	279	+ 1	0.1
Spirits puncheon.	84	1. 1.10	less sp.	40	30	..	840	will	+56.5	
Hogshead.	63	1. 0. 0	gr. than	35	28	..	630	take		
Barrels	42	0. 2.24	water.	32	25	..	420	care of		
Half-hogs.	32	0. 1.24		27	22	..	320	itself.		
							cub. ft.			
Powder case	21.95	0. 1.15	1. 0. 8	21	17	17	3.5	219.5	+56.5	
Barrel		0. 1.26	0. 3. 6	21	17		ought	to pre-	serve it	self.

WEIGHT OF GUNS, CARRIAGES, &c.

Prs.	Weight.	Carriage.	Total.	Charge.	Gun equal in gallons.	Cubic feet.	Pounds.	Division for loss in water.	Calibre.
	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.						
6	20. 1. 0	2. 3. 24	23. 0. 24	⅓ weight	226. 8	36. 29	2268	77	
9	25. 2. 10	3. 3. 0	29. 1. 10	of	286. 6	46. 85	2866	or	
12	32. 0. 0	4. 3. 0	36. 3 . 0	shot.	358. 4	57. 34	3584	⅛th.	
18	36. 0. 0	5. 2. 0	41. 2. 0	..	403. 2	64. 51	4032		
24	47. 2. 0	6. 3. 0	54. 1. 0	...	532. 0	85. 12	5320		
32	49. 0. 0	8. 0. 0	57. 0. 0	..	548. 8	87. 81	5488		
32	54. 2. 0	8. 2. 0	63. 0. 0	..	610. 4	97. 66	6104		
32	63. 0. 0	9. 1. 0	72. 1. 0	..	705. 6	112. 90	7056		
68	50. 2. 0	9. 3. 20	61. 1. 20	Gun carr.	565. 6	90. 50	5656		
		length. feet.							
10*	84. 0. 0	9. 4 †		⅓ weight	940. 8	150. 5	9408		
68	60. 0. 0	9. 0	....	shot.	672. 0	107. 5	6720		
68	50. 0. 0	7. 0	....	..	560. 0	89. 6	5600		
32	63. 0. 0	9. 7	....	..	705. 6	112 ·9	7056		
32	56. 0. 0	9. 6	....	..	627. 2	100. 3	6272		
32	48. 0. 0	8. 0	....	..	537. 6	86. 01	5376		
32	32. 0. 0	6. 6	....	..	358. 4	57. 34	3584		
32	25. 0. 0	6. 0	....	..	280. 0	48. 00	2800		
32	25. 0. 0	5. 4	....	..	280. 0	48. 00	2800		
24	50. 0. 0	9. 6	....	..	560. 0	89. 60	5600		
24	47. 2. 0	9. 0	....	..	532. 0	85. 12	5320		
24	40. 0. 0	7. 6	....	..	448. 0	71. 68	4480		
18	42. 2. 0	9. 0	....	..	476. 0	76. 16	4760		
18	37. 2. 0	8. 0	....	..	420. 0	67. 20	4200		
12	34. 0. 0	9. 0	....	..	380. 8	60. 93	3808		
12	29. 2. 0	7. 6	....	..	330. 4	52. 86	3304		
9	26. 0. 0	7. 6	....	..	291. 2	46. 60	2912		
6	17. 0 0	6. 0	....	..	190. 4	30. 46	1904		

* Inch shot (new gun.) † New Establishment.

CARRONADES.

Pounder.	Weight.	Carriage.	Total.	Charge.	Gun equal to Gallons.	Cubic feet.	Pounds.	Divisor or loss in water.	Calibre.
	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.						
12	6. 1. 0	3. 0. 0	9. 1. 0	weight of	70. 0	11. 20	700	77	
18	10. 1. 0	4. 1. 14	14. 2. 14	$\frac{1}{12}$ shot.	114. 8	18. 30	1148	or	
24	13. 1. 20	5. 2. 0	18. 3. 20		150. 4	24. 06	1504	⅛	
32	17. 3. 0	6. 2. 14	24. 1. 14		198 ·8	31. 81	1988		
42	22. 3. 0	7. 2. 0	30. 1. 0		254. 8	40. 77	2548		
68	36. 0. 0	10. 0. 0	40. 0. 0		403. 2	64. 51	4032		
	New								
42	22. 0. 0				246. 4	39. 42	2464		
32	17. 0. 0				190. 4	30. 46	1904		
24	10. 0. 0				112. 0	17. 92	1120		
12	6. 0. 0				67. 2	10. 75	672		

The following are also extracted from De Chapman:—

Weight of a Cubic Foot (provision weight) of the following articles.							
	lbs.						
Lead.......	672	Sea water..	64.4	Wheat ...	44. 0	Oats	31. 0
Wrought iron	475	Fresh	62.5	Pease	52. 0	Bread rye.	40. 25
Cast iron ...	440	Oak.......	53.0	Finland rye	42. 6	Oatmeal ..	30. 0
Pitch	83	Fir	38.0	Barley ...	39. 5	Malt	28. 9
Tiles.......	116	Lime......	42.0	Barleymeal	36. 18	Biscuit ...	26. 0

	Ft.	In.		Ft.	In.	
A cask of beef, herrings, flour............	2	6	outside length..	3	6	mid. dia.
Hogshead of Bourdeaux wine.............	3	1½	„	2	4	
Cask of brandy containing 3 hds. Bourdeaux	4	1	„	3	0	
Cask of Virginia tobacco	4	0	„	3	0	1200 lbs.
Cask of sugar..........................	4	6	„	3	0	1700
Chest of tea...........................	2	11	by	2	0	

Weight of one foot of iron bar of the following forms:—							
Thickness.	Square.	Octagonal.	Round.	Thickness.	Square.	Octagon.	Round.
Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	29.45	24.27	23.14	1¼	5.11	4.14	4.02
2½	20.45	16.85	16.07	1⅛	4.14	3.41	3.25
2¼	16.56	13.65	13.02	1	3.27	2.70	2.57
2	13.09	10.79	10.29	⅞	2.51	2.06	1.97
1⅞	11.50	9.48	9.04	¾	1.84	1.52	1.45
1¾	10.02	8.26	7.87	⅝	1.28	1.05	1.00
1⅝	8.64	7.12	6.79	½	0.81	0.67	0.64
1½	7.36	6.07	5.78	⅜	0.46	0.38	0.36
1⅜	6.19	5.10	4.86	¼	0.20	0.17	0.16

It is calculated that (on an average) provision, wood, coals, casks, &c. for one man = 186 lbs. per month; water for ditto = 217; man and effects = 260. 186 + 217 + 260 = 663 lbs.

The annexed, are the weights of the following provisions, as supplied by merchants, to shipping, troops, &c.

Beef.	Navy..	304 lbs.	per tierce,	containing	38	pieces of	8 lb.	each.
	India..	336 „	„	„	42	„	8	„
	Mess ..	304 „	„	„	38	„	8	„
	Do. ..	200 „	per barrel	„	25	„	8	„
	Do. ..	100 „	per firkin	„	25	„	4	„
Pork.	Navy..	320 „	per tierce	„	80	„	4	„
	India..	318 „	„	„	53	„	6	„
	Army .	208 „	per barrel	„	52	„	4	„
	Mess..	200 „	„	„	50	„	4	„
	Do. ..	100 „	per firkin	„	25	„	4	„

The coal bushel = 20 in. dia. bottom ; 21 top, = 10 gallons Winchester.

A barrel of whale oil is equal to 216 lbs. or $31\frac{1}{2}$ gallons.

The following are the weights of canvas, in bolts of 38 yards, by 24 inches wide.

Double thread	1 .... 44 lbs.		Single	
	2 .... 41 ,,			7 24
	3 .... 38 ,,			8 21
	4 .... 35 ,,			9 18
	5 .... 32 ,,			10 15
	6 .... 29 ,,			

TABLE OF WOODS.—(Edye †.)

English oak. Cubic foot.	Green=71. 10*	Seasoned=43. 8
Dantzic	49. 14	36. 0
African teak	63. 12	60. 10
Indian teak, Malabar		52. 15
,, Rangoon		26. 4
Indian Mast Peon	48. 3	36. 0
Cedar	32. 0	28. 4
Larch	45. 0	34. 4
Riga fir	48. 12	35. 8
New England	44. 12	30. 11
Elm	66. 8	37. 5
Beech	60. 0	53. 6
Ash	58. 3	50. 0

Thus, De Chapman. Oak 53. Table sp. gr. ,925÷16=57.8= Edye 43 lb. 8 oz.=43.5

The following table exhibits the number of fir planks of different dimensions, which are equal to 1 last of 7.200 lbs.

To use this table, enter with the thickness in inches at top, and width in side column ; the numbers correspond to lengths of six and seven ells respectively.

Breadth inches.	Length in ells, Swedish.	Thickness of plank in inches.				
		1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2
8	6	$18\frac{1}{2}$	$14\frac{3}{4}$	$12\frac{1}{4}$	$10\frac{1}{2}$	$9\frac{1}{4}$
	7	$15\frac{3}{4}$	$12\frac{2}{3}$	$10\frac{1}{2}$	9	8
9	6	$16\frac{1}{3}$	$13\frac{1}{6}$	11	$9\frac{1}{3}$	$8\frac{1}{16}$
	7	14	$11\frac{1}{4}$	$9\frac{1}{3}$	8	7
10	6	$14\frac{5}{6}$	$11\frac{3}{4}$	$9\frac{5}{6}$	$8\frac{1}{2}$	$7\frac{1}{3}$
	7	$12\frac{3}{4}$	$10\frac{1}{16}$	$8\frac{1}{2}$	$7\frac{3}{4}$	$6\frac{1}{3}$
11	6	$13\frac{1}{3}$	$10\frac{3}{4}$	9	$7\frac{1}{4}$	$6\frac{2}{3}$
	7	$11\frac{1}{2}$	$9\frac{1}{16}$	$7\frac{3}{4}$	$6\frac{7}{12}$	$5\frac{3}{4}$
12	6	$12\frac{1}{4}$	$9\frac{5}{6}$	$8\frac{1}{6}$	7	$6\frac{1}{6}$
	7	$10\frac{1}{2}$	$8\frac{1}{2}$	7	6	$5\frac{1}{4}$

* All such proportions must vary considerably. To draw any comparisons, refer to De Chapman's table, and the table of specific gravity ; the latter contains the number of ounces in one cubic foot, ÷ by 16 = the comparison required.

If it exceed two inches, take out the numbers corresponding to one-half, and double them. Eight and a half dozen, of ten inches by one and a half, and seven ells, equal one last =7.200 lbs. = 148 cubic feet. For green plank (fir) add about one-eighth per cent.

******Table showing the linear dilatation of solids and fluids on change of temperatures from 32° to 212°.***

Glass tube (mean 5.)	1.000825	Tin solder	1.002173
Plate glass	1.000878	Pewter	1.002283
Deal	1.000878	Tin	1.002840
Platina	1.000958	Soft solder	1.002508
Cast iron	1.001111	Lead	1.002850
Steel	1.001225	Zinc	1.003000
Iron	1.001220	Mercury	0.018000
Wire	1.001440	Water (from 39°)	0.046320
Gold	1.001513	Muriatic acid	0.060000
Copper	1.001918	Nitric	0.110000
Brass	1.001855	Sulphuric	0.060000
Cast	1.001893	Alcohol	0.110000
Wire	1.001930	Water saturated with salt	0.050000
Silver	1.002100	Fixed oils	0.080000
Spelter solder — brass 2, zinc 1.=	1.002058	Oil of turpentine	0.070000

The following table exhibits the pressure which the substances included will require to crush them.

One cubic inch.

	lbs.		lbs.
Elm	1824	A prism of Craigleith stone	8688
American pine	1606	Purbeck	20610
White deal	1928	Black Brabant marble	20742
English oak	3860	Very hard freestone	21254
A prism of Portland stone 2 in. long	805	White Italian veined marble	21783
Statuary marble	3216	Blue Aberdeen granite	24556

Cubes of 1½ in.

Chalk	1127	Yorkshire paving with and against strata	12856
Brick, pale	1265	Statuary marble not veined	23632
Red	1817	Cornish granite	14302
Yellow faced Hammersmith	2254	Dundee sandstone	14918
Burnt do.	3243	Devonshire red marble	16712
Stowbridge, or fine do.	3864	Compact limestone	17354
Derby grit	7070	Peterhead granite	18636
Do. another quarry	9776	Limerick black compact limestone	19924
Portland stone	10284		
Craigleith white freestone	12346		

* From Ure's Dict. Chemistry.

Cubes of ¼ in.

Cast iron	9773	Wrought copper	6440
Cast copper	7318	Cast tin	966
Fine Yellow brass	10304	Cast lead	483

Bars of metal 6 in. long, and ¼ in. square, suspended by nippers.

Cast iron horizontal	1166	Hard gun-metal	2273
Do. vertical	1218	Wrought copper, by hammer	2112
Cast steel	8391	Cast copper	1192
Blistered, reduced by hammer	8322	Fine yellow brass	1123
Shear steel do	7977	Cast tin	296
Swedish iron do	4504	Cast lead	114
English iron do	3492		

The above result, from a series of experiments conducted by Mr. George Rennie, jun., in 1818, and published in the Philosophical Transactions.

A bar of iron, one inch and a half in diameter, was subjected to trial at the chain cable manufactory of Captain Brown; and it was found to require a force of 43 tons to effect its rupture.

*A wire of zinc 1-10th of an inch in diameter breaks with	26lbs.	Mechenbroek.
Lead	22¼	Emerson.
Tin	49¼	"
Copper	299¼	"
Brass	360	"
Silver	370	"
Iron	450	"
Gold	500	"
A cylinder of Iron, 1 inch	63.320	Rumford.

Iron may be assumed about four times stronger than oak, and six times stronger than deal.

In determining the floating power of a spar, it is necessary to calculate its cubic contents, which is readily done by finding its mean diameter.

Thus, say a spar had the following dimensions:—heel, 13 inches; middle, 12; small end, 11; length 40 feet.

Then 12 is the mean diameter. Now,

All circles are to each other as the squares of their diameters. The area of a circle of one inch diameter is .7853982.

Now, if we add to twice the logarithm of the given circle, (or diameter of spar,) the logarithm of ,7853982 = 9.895090, we obtain the area or superficial content of the circular dimension.

* Ure.

Then, diameter of spar, 12 inches............	1.079181
	2
	2.158362
Log of 1 inch diameter	9.895090
Area in square inches 113,0	2.053462
Multiply by 40 feet = 480 inches	2.681241
Cubic inches 5428.7 = ..	4.734693
Divide by 1728, the number of cubic in. in a foot..	3.237544
Cubic feet 31.416......	1.497149
Now one cubic foot of seasoned Riga fir = 35,8 ..	1.553883
Weight in lbs. = 1124,1.	3.351032

Now, the divisor for wood being about two-thirds, $1124.1 \div 3 = 374.7 \times 2 = 749{,}4$. Therefore the floating power will be about 374.7 lbs., being the difference between its own specific gravity, and that of distilled water.

In constructing a raft, it should be borne in mind; that all the weight of human beings is to be placed on it, and that a great quantity of provision and water may be safely carried under it. All these calculations should be previously made, and a scale formed of the component parts of a raft, if required. For instance, supposing the raft would swim freely and safely with forty men. In making the calculation for provision, the cask of flour slung beneath would only be 116 lbs; but, if *on* the raft = 656 lbs. Beef slung beneath, 20 lbs.; above, 300 lbs. It would not be a bad exercise to construct rafts occasionally. Twice in the year would impress it on the minds of all.

De Chapman gives the following rule for determining the weight of cordage. The square of the circumference divided by 4, equals the weight of a fathom. Thus a cable of 15 in. $15^2 \div 4 = 56\frac{1}{4}$ lbs. Or 4 fathoms, $56, 25 \times 4 = 225$ lbs.

Another Rule:—Multiply the square of the circumference by length in fathoms, and divide by 480 for weight in cwts. Thus $15^2 \times 4 = 900 \div 480 = 1,875 = 210$ lbs., 15 lbs. less than last method.

The following table, although computed 30 years since, does not appear entirely out of place here, as calculations on former experiments, contrasted with those of the present, or intermediate periods are not devoid of interest. A vacant space has been left in each table

for the purpose of inserting the result of experiment, as the differences in manufacture, independent of material, must ever produce variations which no rule can embrace.

The advantage of the present table is, that at sight the weight of a cable, cablet, hawser, &c. is instantly known, which, with the weight of the anchor, men, and geer, guides the officer in estimating what are his powers at command.

TABLES OF WEIGHTS OF CORDAGE.

Inches.	Cables.	Cwt.	Qrs.	Lbs.	Corrected			Inches.	Cablets.	Cwt.	Qrs.	Lbs.	Corrected		
					Cwt.	Qrs.	Lbs.						Cwt.	Qrs.	Lbs.
24	1 fathom to weigh	1	1	4				9½	120 fms. to weigh	22	2	9			
22	,, ,,	1	0	9				9	,, ,,	20	1	17			
20	,, ,,	..	3	16				8½	,, ,,	18	0	26			
19	,, ,,	..	3	6				8	,, ,,	16	0	6			
17	,, ,,	..	2	16				7½	,, ,,	13	3	16			
16	,, ,,	..	2	8				7	,, ,,	12	0	18			
15	,, ,,	..	1	27				6½	,, ,,	10	1	19			
14	100 fathoms ,,	41	2	20				6	,, ,,	9	0	12			
13½	,, ,,	38	3	1				5½	,, ,,	7	3	7			
13	,, ,,	35	3	9				5	,, ,,	6	2	1			
12½	,, ,,	32	3	17				4½	,, ,,	5	0	23			
11½	,, ,,	30	1	10				4	,, ,,	4	0	18			
11	,, ,,	25	5	10				3½	,, ,,	3	1	22			
10½	,, ,,	23	1	17				3	,, ,,	2	2	11			
10	,, ,,	21	0	3				2½	,, ,,	1	3	0			
								2	,, ,,	1	1	4			
	Hawser laid.														
6½	130 fms. to weigh	13	1	11											
6	,, ,,	11	1	13											
5½	,, ,,	9	2	2											
5	,, ,,	7	3	19											
4½	,, ,,	6	1	22											
4	,, ,,	5	0	14											
3½	,, ,,	3	3	7											
3	,, ,,	2	3	20											
2½	,, ,,	2	0	5											
2	,, ,,	1	1	6											
1½	,, ,,	0	3	13											
1	,, ,,		1	20											
¾	,, ,,		1	4											

Table showing the weight of 100 fathoms of cable laid rope from 2 to 26 inches.†

Size.	Threads.	Weight.	Equal to Chain.	Size.	Thr.	Weight.	Chain.	Size.	Thr.	Weight.	Chain.
		cwt. qrs. lbs.				cwt. qrs. lbs.				cwt. qrs. lbs.	
2	27	0. 3. 26		10½	576	21. 0. 19	1	19	1881	69. 0. 17	1⅞
2½	36	1. 1. 8		11	630	23. 0. 18		19½	1980	72. 3. 4	
3	54	1. 3. 25		11½	684	25. 0. 15	1⅛	20	2088	76. 3. 1	
3½	72	2. 2. 16		12	747	27. 1. 23	1⅛	20½	2187	80. 1. 16	
4	99	3. 1. 6		12½	810	29. 3. 3		21	2295	84. 1. 14	2
4½	108	3. 3. 24		13	882	32. 1. 19		21½	2403	88. 1. 10	
5	135	4. 3. 23		13½	954	35. 0. 7	1¼	22	2520	92. 2. 16	2
5½	162	5. 3. 22		14	1026	37. 2. 24		22½	2646	97. 1. 3	
6	189	6. 3. 21		14½	1098	40. 1. 12	1⅜	23	2763	101. 2. 8	2⅛
6½	216	7. 3. 21		15	1170	43. 0. 1		23½	2880	105. 3. 14	
7	252	9. 1. 1		15½	1251	45. 3. 26	1½	24	3006	110. 2. 1	2⅛
7½	288	10. 2. 9		16	1332	48. 3. 24		24½	3132	115. 0. 16	
8	333	12. 0. 26	¾	16½	1413	51. 3. 21		25	3258	119. 3. 2	2⅛
8½	378	13. 3. 15		17	1503	55. 1. 0	1⅝	25½	3393	124. 2. 26	
9	423	15. 2. 25		17½	1593	58. 2. 6		26	3528	129. 2. 22	2⅛
9½	468	17. 0. 22	⅞	18	1683	61. 3. 13	1¾				
10	522	19. 0. 21	1	18½	1782	65. 2. 1					

The divisor in the above appears to be 523. nearly ; or the rule :— Multiply the square of the circumference by the length in fathoms, and divide by 523 = weight in cwts., &c. Taking the rough calculation, the chain cable, in 100 fathoms, may be assumed as double the weight of the hempen of its largest compared size. Thus, the chain of 1⅛=58cwt. 2qrs. 11lbs.= 12½ hemp=29cwt. 3qrs. 3lbs. × 2=59.2.6. The range on the length of bar requisite to complete a chain cable should be between 20 and 22 feet per fathom. And taking 21,4 as a multiplier on the fathom, with the decimal parts, from the weight of iron bar answering to circular bars, we shall not err, in a large cable, more than 5 cwt. in the 100 fathoms ; whereas we have a difference between Brunton's and Brown's at 1⅜, equal to 9 cwt.

The difference between common and patent laid rope has been determined as follows.

* The patent shroud laid rope, made from clean Petersburgh hemp, was found to break at a strain between 6¾ and 7¼ cwt. per inch, of their girth in inches squared. Thus a patent rope of 5 inches girth would require 175 cwt.

Common made rope of the same hemp, having 25 threads in each strand, broke with 5 cwt. per inch ; and fell off, at 130 threads, to 4 cwt. per inch.

† From Edye on Displacement. * Stikeman.

Whale lines are generally $2\frac{1}{4}$ girth, and have 28 threads to the strand, being of the finest quality of hemp. They break under 32 cwt. = from 5 to 6 cwt. per in. rope. Lines from same yarns 2 inch patent, have stood above 2 tons.

It is a mistaken notion that our tanks contain two tons each, or that they contain 64 cubic feet of water. Allowing that each tank is originally filled, it will be found on trial, that on an average, they will not mean more than 47 inches cube on the large, and one inch diminished from the others. This will only afford 60 cubic feet of water, equal to 33 cwt. 2 qrs. 3 lbs.

Table of Avoirdupois Weight, showing the weight in Grains Troy, and its corresponding decimal fraction.

	Troy grs.	Decimal.
1 pound	7000.0	1.0000
15 ounces	6562.5	0.9375
14	6125.0	0.8750
13	5687.5	0.8125
12=$\frac{3}{4}$	5250.0	0.7500
11	4812.5	0.6875
10	4375.0	0.6250
9	3937.5	0.5625
8=$\frac{1}{2}$	3500.0	0.5000
7	3062.5	0.4375
6	2625.0	0.3750
5	2187.5	0.3125
4=$\frac{1}{4}$	1750.0	0.2500
3	1312.5	0.1875
2	875.0	0.1250
1	437.5	0.0625*
15 drams	410.16	0.0586
14	382.81	0.0547
13	355.47	0.0508
12=$\frac{3}{4}$ oz.	328.13	0.0469
11	300.78	0.0430
10	273.44	0.0391
9	246.09	0.0352
8=$\frac{1}{2}$ oz.	218.75	0.0313
7	191.41	0.0273
6	164.06	0.0234
5	136.72	0.0195
4=$\frac{1}{4}$ oz.	109.35	0.0156
3	82.03	0.0117
2	54.6	0.0078
1	27.34	0.0039
$\frac{1}{2}$ dram	13.67	0.0019

* The upper decimals equally apply as decimals of the ounce.

FLUID MEASURE.

1 gallon is equal to 10 pounds of distilled water = 70.000 grains troy.

	lbs.	oz.	cub. inches.	grains.
1 gallon is equal to	10	0	277.2738	70.000
$\frac{1}{2}$ „ „	5	0	138.6369	35.000
$\frac{1}{4}$ = 1 quart	2	8	69.3184	17.500
1 pint	1	4	34.6592	8.750
$\frac{3}{4}$ (or 12 oz. medical)	0	15	25.9944	6.5625
$\frac{1}{2}$	0	10	17.3296	4.3750
$\frac{1}{4}$	0	5	8.6648	2.1875
$\frac{1}{8}$	0	$2\frac{1}{2}$	4.3324	1.0937

The avoirdupois ounce............. 1.73298 cubic inches.
Troy „ .... 1.9013214 „

One cubic inch of water................ weighs 252.456 grains.
cubic foot „ .... „ 62.3206 lbs.
One cubic foot of air, or 1728 cubic inches „ 528.367 grains troy.

The following temperatures, used in philosophical experiments, are not so familiarly known as they should be, and where the excess of boiling point of water, or that below it, may be required, renders the object very simply attainable.

Thus, we also know the points at which the metals become fluid, and by such, they are rendered equally available.

If water be saturated with sugar, or formed into syrup, the boiling point is raised to 221°. Now, in experiments on sulphur, we know that it will not melt until it attain 220°. Therefore, to conduct an operation very delicately, in which it is concerned, it follows that by placing it in a glass vessel floating in syrup, we obtain it in a state of fusion. If subjected to 300° in another vessel, its colour is changed, it becomes thick and viscid, and mars the experiment.

If we wish to warm water, or preserve its temperature in another vessel, it can be effected by surrounding it by a fluid warmer than itself.

Thus, then, we have the following Table:—

	Proportion in 100.	Boiling point.
Acetate of soda	60	256° Fah.
Nitrate of soda	60	246
Rochelle salt	90	240
Nitre	74	238
Muriate of ammonia	50	236

	Proportion in 100.		Boiling point.
Tartrate of potash	68	..	234° Fah.
Common salt	30	..	224
Sulphate magnesia (Epsom)	57.5	..	222
Borax	52.5	..	222
Carbonate of soda	?	..	220
Sulphate of zinc (white vitriol)	45	..	220
Alum	52	..	220
Sulphate copper (blue vitriol)	45	..	216
Sulphate of iron (green vitriol)	64	..	216
Sulphate soda (glauber)	31.5	..	213
Syrup			221
Oil and fatty substances			320
Oil of turpentine			316
Phosphorus			554
Sulphur			570
Linseed oil			640
Mercury			656
Acids .. Muriatic			222 to 232
Acids .. Nitric			220 to 248
Acids .. Sulphuric			240 to 620
Alcohol			173.5
Ether			100

[It is worthy of note, that substances covered by the salts in powder, and subjected to *steam* from water, receive an increase of temperature equal to the above results, as if in solution; and that the steam from such fluids, containing salts, is equal to their boiling temperature.]

Upon these principles, then, the schoolboy's trick of melting lead in a piece of writing paper, by the aid of tallow, is readily accounted for. Such, although a boyish trick, is frequently applied to useful purposes, a candle, paper, tallow, and lead, affording the means of obtaining casts of the latter with great facility; and, on boat service, affording the means of repairing lamps, casting balls, &c., which might otherwise be deemed impracticable.

Steel is tempered by being heated in oil, the temperatures varying from 430° to 600°. Oil, then, is a convenient medium in which the thermometer may safely be immersed, and the heat gradually raised to the required temperature.

We have before remarked, in treating of specific gravity, that the solubility of different salts affords the means of illustrating the difference of specific gravity. The differences of solubility may in many cases be rendered subservient to the elucidation of other experiments.

Thus, common salt, at temperature 109° will only take up 40.38

in 100 parts of water. The anhydrous sulphate of magnesia, or Epsom salt, at 97°. 03, takes up 72.30. The crystallized sulphate, at 97°. 03, takes up 644. 44. Sulphate of soda, or Glauber's salt, at 50°. 40, takes up 262. 35. Nitre at 97°. 66, takes up 236. 45.

It may sometimes be required to obtain alcohol, or spirits of wine, from rum or wine, for the purpose of preserving delicate objects of natural history, and bad wine may be on the point of being thrown overboard. The armourer can always fit a still-head to a saucepan, and the spirit may easily be drawn off. The following scale of such wines as may be supposed to be met with on board, exhibits the quantity of spirit per cent. in each.

Marsala	per cent.	25. 3	to	26. 30
Madeira	,,	19. 41	to	24. 42
Sherry	,,	18. 25	to	19. 81
Teneriffe	,,	19. 19	to	19. 79
Malaga	,,	....		18. 94
Cape Madeira	,,	18. 11	to	22. 94
Claret	,,	12. 91	to	17. 11
Champagne			average	12. 61
Ale and stout			,,	6. 87
Brandy			,,	53. 39
Rum			,,	53. 68
Gin			,,	51. 60
Whisky			,,	54. 0*

From the preceding, fair conclusions may be arrived at, as to the issue of wine or spirits to the crew, or half of each. It must be borne in mind that dilute spirit (rum or brandy) is more likely to allay thirst than wine, particularly in warm climates, where perspiration is excessive. That the wine is more likely to produce a disordered stomach when the party is exposed to much fatigue in the sun, and that if it is to be given as part allowance, it should be after the labour has ceased.

The mean proportion on Teneriffe is 19. 79; allowance one pint. Allow three waters only to be added to the allowance of rum, we have the proportion; 1 gill of rum + 3 gills of water = 1 pint, in which the proportion of spirit is only, in good rum, 53. 68 ÷ 3, or the pint of grog is equal to 17. 89 per cent.

If the boat's crews, then, take their full allowance of wine, and consume it in the heat of the day, they are either half intoxicated, or

* The two latter are sufficiently strong for preserving objects, and gin I have found peculiarly adapted.

knocked up before they have completed their day's work; and probably sick at nights.

These, it may be said, are points left to the surgeon. Not so. When sickness occurs, they go to him for relief; but the officer who serves with them for weeks, without medical assistance, should look to the *prevention* of disease. The health of his party should occupy his first thoughts. His measures for the preservation of their lives may be deemed, at the time, bordering on severity, yet he himself sets the example; and when the hour of trial comes, those very men who before grumbled at restraint are the first to feel hurt, if excluded from forming part of a similar expedition. If the officer possess the confidence of the men under his command—if they fancy he can remedy their complaints without sending them to the list, they will submit cheerfully to much greater privation than they would under the surgeon. It is almost needless to remark, what an advantage such knowledge is to an officer, detached for weeks, with the lives of fifty or sixty men in his hands.

The work of Mr. Edye has been very justly praised by several of the leading periodicals, and therefore any remark may be deemed superfluous here. It is to be regretted that this work is not, like Mendoza Rios' and other less important tables, one of the standing volumes supplied the service. It is valuable in its present state, but every naval man must see, that the author could afford us still more important additions, if it were made government property, and a proper remuneration bestowed on the talent which must be exerted in hours not included in professional duties. As the dimensions, materials, &c. change, we naturally look for information on such heads, but they cannot safely be afforded without the sanction of the "powers that be."

In connexion, then, with the dimensions of ships, we might naturally hope for the measurement from stern to quarter, as connected with the problem for determining distance from enemy. With such materials, the bowsprit, jib-boom, &c. could easily be projected on paper, by using the horizontal distances, obtained by dropping a lead line from each, and projecting spars to meet the perpendiculars.

In comparing the results of French authors, it may not be out of place to introduce here the comparisons between the measures and weights used by both countries. As respects the measures in sounding, they are supplied by the Admiralty, but the general dif-

ference between all nations on this point will be inserted after the general tables of weights and measures, which follow.

The *metre*, upon which the French metrical system, or unit of length, is founded, is equal to one-millionth part of a quadrant of the meridian, or in English measure, to about 39.37079 inches.

Metre is the foundation of the measure of length; gramme, that of weight; which latter is the weight of a cubic centimetre, or a hundredth part of a metre of distilled water at the freezing point,* 32°, equal to 15,434 grains English troy.

The terms employed by the French derive their designation from the Greek and Latin, the former being the multiplier, and the latter the divisor; thus—

	Deca	equals	10 times.
	Hecto	,,	100
	Chilo, or Kilo		1000
	Myria	,,	10.000
And	Deci	,,	10th part.
	Centi	,,	100
	Milli	,,	1000

Thus the deca-metre is equal to ten metres; the deci-metre, the tenth *part* of a metre; the kilo-gramme 1000 grammes.

The *are* is the element of square measure. It is equal to a square deca-metre, or 3.955 English perches = 119.6046 square yards.

The *stere* is the element of the cube, and is equal to 35.317 cubic feet, English.

The *litre* is the element of capacity. It is a cubic deci-metre, and is equal to 2.1135 English pints. One hundred *litres* equal one hecto-litre, or 26.419 English gallons.

COMPARISON OF FRENCH AND ENGLISH MEASURES.

French.	English.	
Milli-metre is equal to	0.03937 inches.	Or by removing the decimal point one place to the right on each.
Centi-metre	0.39371	
Deci-metre..............	3.93708	
Metre	39.37079	

* Water at 32° is not *ice*, as frequently imagined. If water at that temperature be agitated, and the surrounding atmosphere be nearly the same, congelation follows. But Gay Lussac and Sir Charles Blagden reduced water to 21½ Fahrenheit, without congelation. The surface was protected by oil.

	French.		English.
Deca-metre	393.70790	or	32.809166 feet.
Hecto-metre	3937.07900		328.091666
Kilo-metre..............	39370.79000		3280.916666
Myria-metre	393707.90000		32809.166666

Or 6 miles 1 furlong 156 yds. 0 feet, 9.17 inches.

SUPERFICIAL MEASUREMENT.

Centi-are is equal to......	1.1960 square yards.
Are	119.6046
Dec-are.................	1196.0460
Hectare	11960.4604=2 acres, 1 rood, 35 perches.

MEASURES OF CAPACITY.

Cubic inch contains 252.5 imp. grains of water at 62°.

		Imperial.	
		gallons.	pints.
Milli-litre contains cubic inches	0.06112		
Centi-litre	0.61120		
Deci-litre	6.11208		
Litre	61.12079........	0	...... 1.76377
Deca-litre	611.20792........	2	...... 1.44640
Hecato-litre	6112.07920........	22	...... 0.26400
Kilo-litre	61120.79208........	220.47	
Myrio-litre	611207.92080........	2204.71	

WEIGHTS.

		Avoirdupois pounds.
Milli-gramme English grs.	.0154	
Centi-gramme............	.1543	
Deci-gramme	1.5433	
Gramme	15.4330	
Deca-gramme............	154.3300	.... 0.022
Hecato-gramme..........	1543.3000	.... 0.220
Kilo-gramme	15433.0000	.... 2.204
Myrio-gramme	154330.0000	.... 22.047

The English troy pound, of 12 ounces, contains 5760 English troy grains, and is equal to 7021 Paris grains.

The English avoirdupois pound, of 16 ounces, contains 7000 English troy grains, and is equal to 8532.5 Paris grains.

To reduce Paris grains to troy, divide by 1.2189, or multiply English troy grains by the same to reduce them to Paris.

To reduce Paris ounces to English troy grains, divide by 1.015734, or multiply English troy ounces by the same to reduce them to Paris.

To reduce Paris running feet, or inches, into English, multiply by 1.065977, or divide by the same to reduce English into Paris.

To reduce Paris cubic feet or inches into English, multiply by

1.211278, or divide English cubic feet or inches by the same to reduce them to Paris.

LONG MEASURE.

	barleycorns.	inch.	foot.	yard.	pole or rod.	furlong.	mile.	league.	French metres.
1 inch	3	1							0.0254=0.02539954
1 foot	36	12	1						0.3048
1 yard	108	36	3	1					0.9144
pole or rod	594	198	16½	5½	1				5.0291
furlong	23760	7920	660	220	40	1			201.1632
mile	190080	63360	5280	1760	320	8	1		1609.3059
league	570240	190080	15840	5280	960	24	3	1	4827.9179

6075.56 feet = 1 geographic mile; 60 miles 1 degree, or 69 1-9th English = 1 degree. French 11120.7442.

The degree of longitude may be found by subtracting the secant of the latitude from the log. of 60′.

The fathom English is six feet.

Palm .... 3 inches.
Hand 4

SQUARE MEASURE.

	Sq. inch.	sq. foot.	yard.	pole.	rood.	acre.	French sq. metres.
Square foot	= 144	1					0.0929
Square yard	1296	9	1				0.8361
Square pole	39204	272,25	30,25	1			25.2916
Square rood	1568160	10890	1210	40	1		1011.6662
Square acre	6272640	43560	4840	160	4	1	4046.6648

EXTRA MEASURES.

The wood-land pole .... 18 feet.
Plantation 21
Cheshire 24
Sherwood Forest 25
A yard of land .... 30 acres.
A hide 100
A mile 640

CUBIC MEASURE.

		French cubic metres
Cubic foot = 1728 cub. in. = 1 foot.	Cub. yard =	0.0283
27 cub. feet = 1		0.7645
Timber { 40 cubic feet, rough	1 load or ton	1.1326
Timber { 50 ,, hewn	1 load or ton	1.4157
42 cubic feet of articles, 1 ton (of shipping)		1.1892

1000 billets of wood equal .... 1 cord.
10 cwt. of do. .... 1 do.
1 cord of wood is equal to ...... ½ chaldron of coals.
1 quintal of wood .... 100 lbs.

Tables for reducing Foreign Measures used in Surveying into English.

FRENCH.

The *pied* = 1.065977 feet, or = 0.177668 of a fathom. The *toise* = 6.39459259 English feet.

The English foot = 0.15638212 of a *toise*. The *brasse* = 5 *Fr. pieds*, or = 5.329 English feet, or = 0.88814 of a fathom.

Pieds.	English feet.	Fathoms.	Toises or feet.	English feet.	French Toises.	Pieds.	English feet.	Fathoms.	Toises or feet.	English feet.	French Toises.
1	1.065	0.177	1	6.395	0.156	6	6.390	1.062	6	38.368	0.938
2	2.130	0.354	2	12.789	0.313	7	7.455	1.239	7	44.762	1.095
3	3.195	0.531	3	19.194	0.469	8	8.520	1.416	8	51.157	1.251
4	4.260	0.708	4	25.578	0.626	9	9.585	1.593	9	57.571	1.407
5	5.325	0.885	5	31.973	0.782	10	10.650	1.776	10	63.946	1.564

SPANISH.

1 *Castilian braza* = 6 *pies de Burgos* = 5.492 English feet = 0.9153 of a fathom.
The *vara* = 2.742523995 English feet. 1 Eng. foot = 0.364991881 *varas*.

Brazas.	English feet.	Fathoms.	Varas or feet.	English feet.	Castilian varas	Brazas.	English feet.	Fathoms.	Varas or feet.	English feet.	Castilian varas.
1	5.492	0.915	1	2.743	0.365	6	32.952	5.492	6	16.455	2.190
2	10.984	1.830	2	5.485	0.730	7	38.444	6.407	7	19.198	2.555
3	16.476	2.746	3	8.228	1.095	8	43.936	7.322	8	21.940	2.920
4	21.968	3.661	4	10.970	1.460	9	49.428	8.237	9	24.683	3.285
5	27.460	4.576	5	13.713	1.825	10	54.920	9.153	10	27.425	3.650

DANISH.

1 *Favn* = 6 *Danish fod* = 6.1752 English feet = 1.0292 fathoms.
1 Copenhagen foot = 1.0269906 Eng. feet. 1 English foot = 0.9737096 Danish feet.

Favne.	English feet	Fathoms.	Danish or Eng. ft.	English feet.	Danish feet.	Favne.	English feet.	Fathoms.	Danish or Eng. ft.	English feet.	Danish feet.
1	6.175	1.029	1	1.027	0.974	6	37.050	6.174	6	6.162	5.842
2	12.350	2.058	2	2.054	1.947	7	43.225	7.203	7	7.189	6.816
3	18.525	3.087	3	3.081	2.921	8	43.400	8.232	8	8.216	7.790
4	24.700	4.116	4	4.108	3.895	9	55.575	9.261	9	9.243	8.763
5	30.875	5.145	5	5.135	4.869	10	61.752	10.292	10	10.270	9.737

DUTCH.

1 *Palm* = 0.3283 of a foot = 0.05472 of a fathom. 1 *Amsterdam foot* = 0.9286784 Eng.
1 English foot = 1.0767971 Amsterdam feet.

Palm.	English feet.	Fathoms.	Dutch or English feet.	English feet.	Dutch feet.	Palm.	English feet.	Fathoms.	Dutch or English feet.	English feet.	Dutch feet.
1	0.328	0.055	1	0.929	1.077	6	1.969	0.328	6	5.572	6.461
2	0.656	0.109	2	1.857	2.154	7	2.298	0.383	7	6.501	7.538
3	0.984	0.164	3	2.786	3.230	8	2.626	0.438	8	7.429	8.614
4	1.312	0.219	4	3.715	4.307	9	2.954	0.493	9	8.358	9.691
5	1.640	0.274	5	4.643	5.384	10	3.283	0.547	10	9.287	10.768

The Amsterdam *Voet* = 0.92919 of a foot = 0.15487 of a fathom.

RUSSIAN.

1 *Sash* = 3 *arsheens* = 6,9995 Eng. ft. = 1.16658 fms. 1 arsheen = 2.3331666 feet.
1 Petersburgh foot = 1.7656196 Eng. feet. 1 Eng. foot = 0.5663741 Petersb. foot.

Sashes.	English feet.	Fathoms.	Russian or Eng. ft.	English feet.	Russian feet.	Sashes.	English feet.	Fathoms.	Russian or Eng. ft.	English feet.	Russian feet.
1	6.999	1.166	1	1.766	0.566	6	41.996	6.999	6	10.594	3.398
2	13.999	2.333	2	3.531	1.133	7	48.996	8.165	7	12.359	3.965
3	20.998	3.499	3	5.297	1.699	8	55.995	9.331	8	14.125	4.531
4	27.998	4.665	4	7.062	2.265	9	62.995	10.498	9	15.891	5.097
5	34.997	5.832	5	8.828	2.832	10	69.995	11.665	10	17.656	5.664

PORTUGUESE. 1 Lisbon *palm* 0.7171718 English feet. 1 English foot = 1.394374 *palms.* 1 fathom = 8.366244 palms.

NOTE.—These have been constructed from Tables published by the Hydrographical Office, and those in the Nautical Magazine.

ASTRONOMICAL OBSERVATIONS.

WE now arrive at that part of our operations which calls for no ordinary share of attention—the determination of the positions in latitude and longitude to the utmost precision, by common instruments, and with that degree of expertness which rapid surveys require. The various works on nautical astronomy and navigation are of course available, and those who have been taught from any particular author will naturally cling to his methods. The formulæ for determining such results can be used at pleasure, but the practical observer may be permitted to point out the most convenient methods of making such observations, and rendering them also available, beyond their common purposes, for time, particularly when so situated that the sun's meridian altitude is too great to be observed in an artificial horizon, or cannot be observed from want of terra firma at that period. The latitude may be approximated by equal altitudes some hours distant from noon, and in high northern or southern latitudes, to very great nicety.

The alteration in the Nautical Almanac also requires some little explanation to those who have merely worked "*by book;*" and, as but too frequently has been noticed, cannot get on without the works and tables *they have learnt from.* This is a serious charge against the system of exclusive tables for correction, and it ought not to be so. Those who instruct our youth in these branches should cause them to investigate the formulæ by which the tables have been constructed, and should render them perfectly independent of such aids.

First, then, let us commence with such a series of observations as a zealous observer would be supposed to make on a spot which was considered doubtful in latitude and longitude, and show how far his purpose is attained by the sacrifice of five or six hours solely to this end.

At a position considered doubtful, in estimated lat. 28° 25′ 30″ N. and longitude $1^{h.}$ $6^{m.}$ $15^{s.}$ in time, west of the meridian of Greenwich, the following series of observations were taken to determine the time, latitude, and longitude; the chronometers having been satisfactorily rated, 48 hours previously, at a well determined position Thermometer 90°, barometer 30.12 in.

☾ 5 VIII/32. Station A.

Times—A.M.			Altitudes.			Corresponding times—P.M.
h. m. s.			° ′			h. m. s.
23. 7.55	..	..	112. 0	..	..	3.44.19.5
8.18.5	..	..	10	..	..	43.55.5
8.41	..	..	20	..	..	43.33
9. 4.5	..	..	30	..	..	43. 9.5
9.29	..	..	40	..	..	42.46
9.52.5	..	..	50	..	..	42.23
10.15.5	..	..	113.00	..	..	41.59.5
10.39	..	..	10	..	..	41.36.5
11. 1.5	..	..	20	..	..	41.13
11.25.5	..	..	30	..	..	40.49.5
11.48.5	..	..	40	..	..	40.27
12.12.5	..	..	50	..	..	40. 3
12.36.5	..	..	114.00	..	..	39.39.5
12.59.5	..	..	10	..	..	39.16.5
13.23	..	..	20	..	..	38.52.5
13.45.5	..	..	30	..	..	38.30
h. m. s.			° ′			h. m. s.
23.37.26.5	..	..	124.30	..	..	3.14.49.5
37.51.5	..	..	40	..	..	14.26
38.17	..	..	50	..	..	14. 1
38.39.5	..	..	125.00	..	..	13.37.5
39. 4	..	..	10	..	..	13.13.5
39.28	..	..	20	..	..	12.49.5
39.51.5	..	..	30	..	..	12.25
40.14.5	..	..	40	..	..	12. 0.5
40.38.5	..	..	50	..	..	11.36
41. 3.5	..	..	126.00	..	..	11.11.5
41.28.5	..	..	10	..	..	10.47
41.52	..	..	20	..	..	10.23
42.17	..	..	30	..	..	9.59.5
42.41	..	..	40	..	..	9.35.5
43. 4	..	..	50	..	..	9.11.5
43.28	..	..	127.00	..	..	8.47.5

h. m. s.			° ′			h. m. s.
11.55.46.5	..	..	132.00	..	..	2.56.28.5
56.10.5	..	..	10	..	..	56. 4
56.36	..	..	20	..	..	55.38.5
18.33						.11
11.56.11						2.56. 3.66

The means of the first, centre, and last tens, in each set, are to be taken, which, with the last three at high altitudes, afford seven sets.

The altitude instrument was then used for carrying on the observations to the meridian altitude, and those corresponding to the forenoon; thus affording a continual series from nine A.M. until three P.M. The corresponding observations to those taken before 23 h. 7 m. 55 s. were lost, the sun not being visible, and therefore do not appear. And, to render these examples simple, only those zenith distances used for circum-meridian sights, and the *means* of three sets of zenith distances for time, will be introduced.

	h. m. s.		° ′ ″
Thus, at	0. 50. 23. 1	the mean Z. D. =	14. 24. 20. 5
at	0. 56. 11. 6	....	13. 40. 40
at	2. 2. 40. 1	....	14. 30. 47

Observations for circum-meridian. Z. D.

Times.		Z. D. right.		Z. D. left.		Z. D.
h. m. s.		° ′ ″		′ ″		° ′ ″
1. 19. 51. 5	..	11. 52. 20	..	52. 5	..	Mean 11. 52. 12. 5
20. 44	..	51. 30	..	51. 40	..	51. 35. 0
21. 54	..	49. 20	..	49. 40	..	49. 30
23. 58	..	46. 10	..	46. 20	..	46. 15
25. 5. 5	..	45. 50	..	46. 10	..	46. 00
25. 53	..	45. 20	..	45. 30	..	45. 25
Noon. Mer.* alt.	..	45. 30	..	45. 40	..	45. 35
30. 8	..	47. 20	..	47. 40	..	47. 30
30. 52	..	48. 20	..	48. 50	..	48. 35
31. 31	..	49. 50	..	49. 50	..	49. 50
32. 54. 5	..	52. 30	..	52. 20	..	52. 25

The above would have been taken more nearly to the system of equal altitudes, but the local position of the instrument (on a narrow

* Not included in times.

wall) rendered it inconvenient, and much time was lost, as the afternoon sights evince.

With the present data we then proceed. First, to determine the apparent time by equal altitudes.

It is necessary to observe, that the formula generally made use of was that of Professor Inman. By the data afforded in the present Nautical Almanac, it will be necessary to multiply the hourly change of declination by 24, to obtain the daily variation. And, as it frequently occurs that youngsters are puzzled to work by other tables when they have learnt by those of Professor Inman, it may be as well to point out on what principle the tables headed "Greenwich date Logarithm for Moon," and "Greenwich date Logarithm for Sun," are formed.

For instance; let it be required to obtain the Greenwich date logarithm for the moon, to 0h. 10m.

From the table of proportional logarithms take out the log. for 0° 12′ = 1.17609, and find its ar. comp.	8.82391
From the same table take out 10 seconds	3.03342
The sum equals 0 h. 10 m. in the table for Gh. date log.	1.85733

Again, let the time be 4 h. 10 m. 12′ ar. comp.	8.82391
Prop. log. for 4 *minutes* and 10 *seconds*	1.63548
Equals the log. in that table for 4 h. 10 m.	0.45939

And if this method is to be closely pursued, the table of seconds and tenths, with the constant log. (of ar. comp. of 12′,) saves much trouble. On the same principle, the "Greenwich date log. for the sun," (being calculated on 24 hours,) 24′ ar. comp. is to be made use of.

Thus, let it be required to find the log. to 7 h. 21 m.

Then, 24′ ar. comp.	9.12494
To 7 m. 21 s.	1.38899
Equals 7 h. 21m. in the table	0.51393

Thus, then, the excuse but too frequently offered, ought to be met instantly by the teacher proving that any tables are available. No-

thing clogs the beginner more than mystery, and possibly it may induce a distaste for further exertion.

It has been necessary to say thus much, as the first term in the professor's formula is the "Greenwich date logarithm for the moon." As the work may not be at hand, the rule will be given in as few words as it can fairly be reduced to.

Having found the difference between the times of observation, the half difference, and applied this half to the time of the first, or morning observation, the result is the *approximate* time of passage. Correct the declination for the apparent time at Greenwich, diminished by the half-interval.

Under the marks (1) and (2) place Greenwich date logarithm for moon, corresponding to the *elapsed interval;* also the prop. log. for the change of declination in 24 hours; then under (1) place the *log. sine* of the *half-interval,* and under (2) its *log. tangent.* Again, under (1) the log. *cotan.* of the lat., and under (2) the *cotang.* of the reduced declination.

The prop. logs. of the sums of these numbers afford the equations.

If the declination is *decreasing,* and of the *same* name with the latitude, or *increasing* and of a *different* name, mark No. 1 + ; otherwise mark it —. No. 2 takes its sign from the declination + when increasing, and — otherwise.

If the signs be similar, take their sum, otherwise their difference, the result taking the sign of the greater.

The minutes are to be considered as seconds, and the seconds, divided by 6 = tenths. This, applied to the approximate time of passage, gives the apparent time of transit by the watch, and its deviation from 24h. 0m. 0s., its error on app. time. By applying the reduced equation of time to 24h. 0m. 0s. the mean noon at place will be found; and applying the longitude in time, that at Greenwich. The error on either may then be found. But, if the longitude is to be determined, the rate of the chronometer must be reduced to the actual instant of *mean time at Greenwich,* and its difference between mean time at place, equals the longitude.

When chronometers have large rates, and particularly the *working* chronometer, amongst a large number, it is necessary to reduce its error to mean *noon* at place, as that found is only its error on mean time *at app. noon;* and where the equation amounts to 16 minutes, and great nicety is required, this quarter of an hour's rate eventually

becomes of importance. Thus, let the rate = 16^s.0 per diem = ,666 hourly = ,166 in 15 minutes.

We will now proceed with the work. The mean of the first ten.

☾ 5 VIII/$_{32}$.

h. m. s.		Change 24 h.	16′ 19″		h. m. s.
23 9 40.2 A.M.		Decl.	16 56 55	App. noon	24 0 0
27 42 34.5 P.M.		Corr.	47.6	Long.	1 6 0
4 32 54.3	Elapsed interval.		16 56 42.6	Gh.	25 6 0
				½ interval	2 16 0
2 16 17.15	½ interval.				22 50 0
25 26 7.35	Sum of ½ int. and A.M. time.				
+ 3.183					

		(1.)			(2.)	
25 26 10.533 app. noon.		42117	=	Gh. date log. ☾ =		42117
		1.04264	=	Prop. log. change dec. =		1.04264
	Sine ½ interval	9.748828			Tang. ½ interval	9.830832
	Cotan. lat.	0.266753			Cotang. dec.	0.516154
	+ 5 58 =	1.479391			−2 47 =	1.810796
	− 2 47					
	+ 3 11 =	3.183				

As there is no necessity to repeat the names, they will be omitted.

h. m. s.		
23 10 50.5	(1.)	(2.)
27 41 24.65	42436	42436
	1.04264	1.04264
4 30 34.15	9.745546	9.826061
	0.266753	0.516154
2 15 17.075		
	+ 5 58 = 1.479299	− 2 47 = 1.804215
25 26 7.575	− 2 47	
+3.183		
	+ 3 11 = 3′.183	
25 26 10.758		

h. m. s.		
23 12 0.65	(1.)	
27 10 14.7	42920	4292
	1.04264	1.04264
4 28 14.05	9.742223	6.821263
	0.266753	0.516154
2 14 7.025		
	+ 5 57 = 1.480816	−2 47 = 1.809257
25 26 7.676	− 2 47	
+ 3.166		
	3 10 = + 3.166	
25 26 10.841		

h. m. s.
23 39 15.45
27 13 1

3 33 45.55

1 46 52.775

25 26 8.225
+ 2.90

25 26 11.125

Dec. red. to 2nd set = 16° 56′ 22″

(1.)
52692
1.04264
9.652856
0.266753

+ 5 50 = 1.489169
− 2 56

+ 2 54 = + 2.9

(2.)
52692
1.04264
9.701908
0.516305

− 2 56 = 1.787773

h. m. s.
23 40 27.7
27 11 48.3

3 31 20.6

1 45 40.3

25 26 8.0
+ 2.883

25 26 10.883

(1.)
53305
1.04264
9.648279
0.266753

+ 5 49 = 1.490722
− 2 56

+ 2 53 = 2.883

(2.)
53305
1.04264
9.696178
0.516305

− 2 56 = 1.788173

h. m. s.
23 41 39.85
27 10 35.7

3 28 55.85

1 44 27.925

25 26 7.775
2.866

25 26 10.641

(1.)
53719
1.04264
9.643633
0.266753

+ 5 49 = 1.490216
− 2 57

+ 2 52 = + 2″.866

(2.)
53719
1.04264
9.690415
0.516305

− 2 57 = 1.786550

h. m. s.
23 56 11
26 56 3.66

2 59 52.66

1 29 56.33

25 26 7.33
2.766

25 26 10.096

Red. decl. 3rd set 16° 56′ 11″

(1.)
60206
1.04264
9.582558
0.266753

+ 5 46 = 1.494011
− 3 0

+ 2 46 = + 2″.766

(2)
60206
1.04264
9.616894
0.516388

− 3.0 = 1.777982

Reduction.

h. m. s.				h. m. s.
25 26 10.533	1st set.		App. noon	24 0 0
10.758	2nd		Equation of time....	5 39.907
10.841	3rd			
11.125	4th		Mean noon	24 5 39.907
10.883	5th			25 26 10.697
10.641	6th			
10.096	7th		F. M. T...........	1 20 30.790
			Corr. to mean noon .	.056
4.877				
		h. m. s.		1 20 30.734
25 26 10.697=chr.		1 26 10.697 F. A. T.	Chr. at noon=14. 15,210 + diff. ,356	14 15.566
			Long.	1 6 15.168

Having, then, obtained the error on apparent time, mean time, and the longitude, let us proceed with the materials we have, to obtain the latitude. The circum-meridian distances are first in importance. We are first to class the times, and find the intervals from noon.

	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
	1 19 51.5	1 20 44	1 21 54	1 23 58	1 25 5.5
Error on A. T.	1 26 10.7	1 26 10.7	1 26 10.7	1 26 10.7	1 26 10.7
Time from noon	6 19.2	5 26.7	4 16.7	2 12.7	1 5.2

	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
	1 25 53	1 30 8	1 30 52	1 31 31	1 32 54.5
	1 26 10.7	1 26 10.7	1 26 10.7	1 26 10.7	1 26 10.7
Time from noon	0 17.7	3 57.3	4 41.3	5 20.3	6 43.8

Take out the versed sines of the arcs, corresponding to these times, and divide their sum by the number of observations.

Also, determine the mean of the zenith distances, and the middle, or between the times nearest noon.

Arcs.		Versi.
6.19.2	....	380
5.26.7	....	282
4.16.7	....	174
2.12.2	....	46
1. 5.2	....	11
0.17.7	....	1
3.57.3	....	149
4.41.3	....	209
5.20.3	....	271
6.43.8	....	432
		10) 195,5

To the constant log.	8.536270
Add. Log. Nat. No. versi, 195.5..........	2.291147
Cosine of estimated lat.	9.944207
Cosine of declination	9.980784
* And the secant of the difference between the corrected sum of altitudes and middle	0.699301
Or, 2′ 48″,3 = 28.3	1.451710

* *Vide* next page.

Middle Z. D.	11° 45′ 42″.5	Mean of Z. D.	11° 48′ 55″.72
Ref.	9.7	Ref.	9.72
	11 45 52.2		11 49 5.47
Semi-dia.	15 48.1	Semi-dia.	15 48.1
	11 30 4.1		11 33 17.37
			90 0 0
T. alt.	78 29 55.9		
	26 42.63 t. alt.	T. alt.	78 26 42.63
		Corr.	+ 2 48.3
	16 38.53		
			78 29 30.93
	78 28 19.26 mid. alt.		
		Z. D.	11 30 29.07
		Dec.	16 55 9.12
		Latitude =	28 25 38.19 N.

In Professor Inman's former edition of his work on Navigation, a method was given for determining the latitude, by altitudes taken near the meridian. This method was constantly made use of on the Blossom's Expedition, and during the passage to India the subject constantly occupied my mind, in order to apply it effectually to equal altitudes, taken at considerable intervals apart. On the passage home, in the Java, it was strictly tested by three to four sets of observations, A. M. and P. M. almost daily, and the results were so complete as to be quite independent of the sun at noon. These were subsequently referred to observations conducted on shore, and after an interval of five years the practice has but seldom been omitted.

The preceding observations, then, will be used for this purpose, remarking, however, that great caution should be observed in taking the altitudes, and determining the error of the sextant. None are free from errors of this nature, therefore, although in some cases the results may differ widely, yet when it is considered that it is only an approximation, the mean of a series, when no meridian observations can be had, must be a considerable relief to the surveyor, or navigator.

Rule for determining the Latitude by Altitudes off the Meridian, when apparent Time is accurately known, and more particularly applicable to equal Altitudes.

To the observed times apply the error on mean time, deduced from the rate of the chronometer *to that instant,* and apply the reduced equation with its *contrary* sign, the result will be the hour angle from noon. Correct the sun's declination to the same instant.

To the secant of the hour angle, (reduced to degrees, minutes, &c.,

if convenient,) add the tangent of the declination, the sum is the tangent of arc A., to be placed under declination, as in formula. Take out the cosine of arc A., and place it under its tangent, then the cosecant of the declination, and the sine of the true altitude. The sum of these four is the cosine of arc B., which being placed under A., their sum, or difference, equals the latitude. The result on the morning and afternoon sets may differ, but the mean will seldom be far wrong.

The corrections for declination and equation are here taken on the middle time of each *set*, but for accuracy should be reduced on each observation.

We will now proceed to determine the latitude by this rule, from the preceding equal altitudes taken for time.

Determination of the Latitude by equal Altitudes.

Barometer 30° 12′. Thermometer 86°.

h. m. s.			° ′ ″		h. m. s.
23 9 40.2		2)	112 45 00		27 42 34.5
1 20 30.79	F. M. T.		56 22 30	F. M. T.	1 20 30.79
21 49 9.41		Ref.	— 31		26 22 3.71
+ .653	rate fr. noon.		56 21 59	Rate	— .693
21 49 10.063		S. dia.	15 48.1		26 22 3.017
— 5 40.478	eq. time.	T. alt.	56 37 47.1	Eq. time	— 5 39.310
21 43 29.585				T. fr. noon	2 16 23.707
2 16 30.415	t. fr. noon.				

	Decl.		Equation.		Decl.	Equation.
	° ′ ″	′ ″	m. s.		° ′ ″	m. s.
	16 55 55	var. 16 19	5 40.2	h. var. ,238	16 55 55	5 40.2
Corr.	+ 47.6		+ .278		— 2 16	— .890
	16 56 42.6=red. dec.		5 40.478	R. E.	16 53 39	5 39.310

	h. m. s.					h. m. s.
T. fr. noon	2 16 30.4	Sec.	0.082074	0.081931	sec. t. fr. noon	2 16 23.7
Decl.	16° 56′ 42″.6	Tang.	9.483851	9.482462	tang. decl.	16° 53′ 39″.0
Arc A. ..	20 12 25	Tang.	9.565925	9.564393	tang. arc A.	20 8 29.0
		Cosi. A.	9.972412	9.972595	cosi. A.	
		Cosec. dec.	0.535426	0.536697	cosec. decl.	
		Sin. t. alt.	9.921756	9.921756	sin. t. alt.	
Arc B. ..	8 13 0	Cosi. B.	9.995519	9.995441	cosi. B.	8 17 16
Lat.	28 25 25	......	[Mean Lat.	28 25 35.75]	....	28 25 45

	Times.	Double alt.	Declination.	Equation.	Latitude.	Mean height.
	h. m. s.			m. s.		
No. 2.	23.10.50.50	113° 15′ 0″	16° 56′ 42.6	5.39.922	28° 25′ 43.5	28° 25′ 43.5
	27.41.24.65		16.53.35.0	5.39.310	28.25.41.5	
No. 3.	23.12. 0.65	113.45. 0	Same as above.		28.26.13.5	28.25.50
	27.40.14.70				28.25.26.5	
No. 4.	23.39.15.45	125.15. 0	16.56.22.2	5.40.36	28.25.36	28.25.19.5
	27.13. 1.00		16.53.54.7	5.39.412	28.25. 3	
No. 5.	23.40.27.71	125.45. 0	Same.		28.25.33.5	28.25.25.21
	27.11.48.30				28.25.17.0	
No. 6.	23.41.39.85	126.15. 0	Same.		28.25.21.0	28.25.18.0
	27.10.35.70				28.25.15.0	
No. 7.	23.56.11.00	132.10. 0	16.56.11.3	5.40.53	28.25. 3.5	28.25.26.7
	26.56. 3.66		16.54. 9.0	5.39.51	28.25.50	
		Z. D.				
No. 8.	24.50.23.1	14.24.20.5	16.55.35	5.40.09	28.25.30.0	28.25.30.0
No. 9.	26. 2.40.1	14.30.47.0	16.54.16	5.39.77	28.25.50.5	28.25.50.5
No. 10.	25.56.11.6	13.40.48	16.55.26.5	5.40.03	28.25. 4.2	28.25. 4.2
					Mean by 1st set.....	28.25.35.7
Noon		11.45.35	16.55.9.12		28.25. 5.5	
						302.6
					Mean Lat.	28.25.30.26
					By sextant alone ...	33.3
					By circum-merid. alt.	38.2

The first set is worked out in full to show the formula; the times, double altitudes, reduced declination, equation, and resulting latitudes only, are given for the remainder. Nos. 8, 9, 10, and noon, are by a transit theodolite, and the zenith distances are the *means* of the readings* in the magnetic meridian.

These examples are introduced to show that observations, taken without precise regard to the latitude, may, if the error of the instrument be truly known, and conducted with moderate attention, materially contribute to multiply such results where the meridian altitude cannot be had at noon, and where landing at night, for its determination by stars, is impracticable, or attended with risk. The corrections for declination and equation could of course be applied to every observation, but the mean of the times of the sets, included in five minute intervals, has been taken to make it simpler, as the same logarithms for the set are repeated for declination. The last three are given to show that equal altitudes are not *necessary*, if apparent time be truly known.

By an altitude instrument, no just result can be expected from its

* The variation was also determined by repeated readings in the magnetic meridian.

reversion in azimuth, as the reading on the circle and the difference of the verniers involve too many errors. If this instrument is to have fair play, it should be used, for at least 24 hours, on one bearing of the axis, then be *reversed* (*on its axis*) for the next 24; and the same pursued when reversed in azimuth. It may be asked, why these circles are not generally constructed to meet this? It would require another set of reading microscopes in the larger instruments, but those with plain verniers could be very easily fitted to derive this very important advantage.

The preceding observations were made under great disadvantages, viz. the intense heat acting on the instruments; the very doubtful state of the atmosphere; and they were not taken with a further view at the *time*, than determining the longitude by meridian distance from the last place of rating; therefore, the error of the instrument, (as no meridian altitude could be had by it) was not then determined.

The following, for time, were taken at Oporto; the error unfortunately not determined on *that day*.

♄ 15 XI/$_{32}$. Lat. of position assumed 41° 8′ 40″ N. Longitude in time 0 h. 34 m. 24 s. W. Barometer 30.20; thermometer 68°.

The means of sets of observations for equal altitudes were as follow:—

h. m. s.	Var. 24 h. 15′ 15″	h. m. s.
20 10 55.2 A. M.	Decl. 18 34 46	24 0 0
25 19 20 P. M.	Corr. 1 14	34 24
5 8 24.8 elapsed interval.	18 33 32	24 34 24 app. t. Gh.
		2 32 24 mean interval.
2 34 12.4 ½ interval.		22 3 0
22 45 7.6 approx. pass.		
11.9		
22 45 19.5		

	(No. 1.)		(2)
	36878	= Gh. date log. ☾ =	368780
	1.07200	= p. log. var. decl. =	1.072000
Sin. ½ int.	9.794642	tangent ½ int. =	9.901409
Cot. lat.	0.058541	Cot. dec. =	0.473999
+ 9 9 P. L.	1.293963	+2 45 P. L.	1.816188
+ 2 45			
+11 54 = 11″ 90			

(No. 2.)

h. m. s.				
20 12 41.7		(1)		(2)
25 17 33.4		.37303		37303
		1.07200		1.07200
5 4 51.7		9.790383		9.894489
		3.058541		0.473999
2 32 25.85				
	+ 9 9	1.293954	+ 2 46	1.813518
22 45 7.55	+ 2 46			
+11.916				
	+11 55=11″.916			
22 45 19.466				

To those inclined to work to the greatest nicety, and who can *spare time*, perhaps the introduction of Mr. Galbraith's method may not be considered out of place. His work should be in the hands of all who take an interest in accurate calculations, but is rather beyond the beginner.

Thus, in the above example.

To the log. cot. Lat.	41° 8′ 35″ =	0.058648	Const. log.	5.364517
Add the cosi. ½ int.	2h. 32m. 25s..8	9.895894	Cotang. ½ interval	0.105511
Arc 1....	42° 0′ 25″ Cotang.	9.954542	Cosec. arc 1	0.174431
Pol. dist..	108 33 32....................		Cosec. Pol. dist. .	0.023193
Diff.	66 33 7 = Arc 2............		Sine arc (2)	9.962569
Elapsed time	5 4 51 = 304.9 in minutes			2.484157
Daily var. decl.	15 15 in seconds = 915			2.961421
			Eq. to eq. alt. = 11″.907......	1.075799

+ when applied to noon if polar distance is increasing, otherwise —. If to Midt. + if polar distance is *decreasing*, otherwise —.

The remainder of the observations will be given, but with their results only, which may serve for practice.

h. m. s.	h. m. s.	h. m. s.	h. m. s.
20 16 37.9 25 13 37.2	22 45 19.466	20 11 51.4 25 19 10.65	22 45 19.925
20 15 22.0 25 14 53.65	22 45 19.741	20 34 1.6 24 56 13.1	22 45 19.20
20 39 40.1 24 50 32.4	22 45 18.116	20 36 50.2 24 53 23.55	22 45 18.603

Reduction....	23 45 19.500
	19.466
	19.466
	19.925
	19.741
	19.200
	18.116
	18.608
	74.022
	22 45 19.253
M. T. place	23 44 49.691
F. M. T. place	0 59 30.438
Slow A. T.	1 14 40.747

We then proceed, as before, to determine the latitude from each set.

Times A.M.		1st Set.		Times P.M.
h. m. s.		Double Alt.		h. m. s.
20 10 55.2		40° 20′ 0″		25 19 20
*+ 59 30,466	S M T.	Ind. error. — 10	S M T.	+ 59 30.466
21 10 25.666		2)40 19 50		26 18 50.466
— 1.496	Corr. rate.	20 9 55	rate ..	+ 1.224
21 10 24.170		Rep. — 2 24.4		26 18 51.690
+ 15 11.492	Equ.	20 7 30.6	Eq. time ..	+ 15 9.370
21 25 35.662		Sem. dia. 16 12.7		2 34 1.060
2 34 24.338	t. f. noon. T. Alt.	20 23 43.3		

Decl.		Equation.		Decl.		Equation.	
						m. s.	
18° 34′ 46″	Var. 15′ 5″	15 10″.6	Var. 11″.1	18° 34′ 46″		15.10. 6	
—1.13	Corr.	+ 892	Corr.	+ 1.55	Corr.	—1.23	
18.33.33	Red. dect.	15.11.492	Red. eq.	18.36.41	Red. dec.	15. 9.37	Red.eq.

	h. m. s.			h. m. s.
Time fr. noon	2 34 24.3	Sec. 0.107067	0.106481 sec.	t. f. noon 2 34 1
Decl.	18° 33′ 33″	tang. 9.526018	9.527319 tang. decl.	18° 36 41″
Arc. A.	23 14 58	tang. 9.633085	9.633800 tang. arc. A....	23 17 1
		Cosi. A. 9.963218	9.963109 cosi. A.	
		cosec. dec. 0.497186	0.496008 cosec. decl.	
		sin. t. alt. 9.542196	9.542196 sin. t. alt.	
Arc. B.	64 23 34	cosi. B. 9.635685	9.635113 cosi arc. B.	64 25 44
Lat.........	41 8 36...........	[Mean Lat. 41° 8′ 39″.5]........		Lat. 41° 8′ 43″

* Error reduced to *mean noon*.

	Times.	Double alt.	Decl.	Equation.	Latitude.
	h. m. s.				
2nd Set.	20.12.41.7 25.17.33.4	40° 44′ 50″		Same as above.	41° 8′ 41″.0 41. 8.50.0
No. 3.	20.16.37.9 25.13.37.2	41.39.50		Same.	41. 8.39.5 41. 8.24.0
No. 4.	20.11. 5.4 25.19.10.65	40.22.20		Same.	41. 8.30.5 41. 8.34.0
No. 5.	20.15.22.0 25.14.53.65	41.22.20		Same.	41. 8.38.0 41. 8.37.5
No. 6.	20.34. 1.6 24.56.13.1	45.29.50	18° 33′ 47″ 18.36.28	15.11. 3 15. 9.37	41. 8.28.0 41. 8.24.5
No. 7.	20.39.40.1 24.50.32.4	46.39.50		Same.	41. 8.21.5 41. 8.38.0
No. 8.	20.36.50.2 24.53.23.35	46. 4.50		Same.	41. 8.31.5 41. 8.44

Without reducing the means from opposite sides, we will take them separately A.M. and P.M.

	A.M.		P.M.
Thus, 1st set, A.M.	41° 8′ 36″.0	P.M.	41° 8′ 43″0
	41.0		50.0
	39.5		24.0
	30.5		34.0
	38.0		37.5
	28.0		24.5
	21.5		38.0
	31.5		44.0
Mean A.M.........	41. 8.33.25	Mean P.M.....	41. 8.36.88

Mean lat. = 41° 8′ 35″.06 N.

These observations were not made with the best instrument, but they differ but 10″ from the mean of a series, taken expressly for the determination of the position, by circum-meridian and meridian altitudes, as well as means of equal altitudes.

Determination of the Latitude by the Meridian Altitudes.

This is an every-day observation, but it were to be wished that more minuteness attended such observations, their reduction, and registry.

So long as a careless system of observing and working continues, no value will attach to the results. The object, of passing at the college attained, books and instruments, are neglected, simply because what has been learned never interested the student.

The meridian altitude, by the sea horizon, cannot be depended on to any great nicety, but, nevertheless, the *system* of working to minute corrections is not, on that account, to be neglected. Constant adherence to a close habit of observing, and working, induces the student to place some value on his calculations, and after years have rolled by, he will refer to them with infinite satisfaction.

The common practice, makes a conglomerate of semi-diameter, dip, refraction, and parallax, assumed perhaps at eleven or twelve minutes, and the estimated declination, as roughly applied, gives the latitude.

Example only, will induce the juniors to attend to these duties; any attempt to exact such, creates a distaste, which probably lasts through life.

The observed altitude is first to be corrected for index error; which has already been treated on at page 7. The refraction is next to be determined, and parallax applied to it.* The dip and semi-diameter are then used. This is the true altitude, which, subtracted from 90°, gives the zenith distance. The declination is now to be corrected for the longitude of the position. Thus, supposing the longitude in time to be 1 h. 30 min. west of Greenwich, and the date August 1st, 1834, the declination at *apparent noon*, by the Nautical Almanac, is 18° 6′ 20″,5 N., and the hourly difference, 37″,96 decreasing. As it is 1 h. 30 min. past noon at Greenwich, or decimally 1,5; 37″,96 × by 1,5 = 56″,94, which, subtracted from the declination, gives 18° 5′ 23″,56 N.

Then, if the zenith distance and declination are both north, or south, their sum will be the latitude. If, one north, and the other south, their difference, of the same name, as the greater. By this

* In the former Nautical Almanac, the tables for minute correction of the refraction were inserted, but are now omitted. Galbraith's, if at hand, (and should be for the surveyor,) has very convenient tables, if not, those in other works must be used as closely as they will admit.

new arrangement in the Nautical Almanac Tables for this purpose are superseded.

When these minute corrections are lost sight of in declination, semi-diameter, refraction, parallax, and probably index error, it is not surprising that differences of 10 or 20 seconds creep in elsewhere. Without a system of close work, the mean of a series of indifferent observations only can be obtained, and probably the errors may all be on *one* side.

The other differences in the Nautical Almanac are similarly used, and entirely supersede the tables for such purposes; indeed, they seldom approached nearer than seconds, whereas we now gain two to three places of decimals.

Observing for Time, or determination of Longitude by Chronometer.

It frequently happens, that when the weather is cloudy, some anxiety is evinced to obtain the sights during the first bright interval. It should always be borne in mind, that under such circumstances the meridian observation will be doubtful. To meet this, after the first sights, obtain, between that period and noon, altitudes at even degrees or minutes on the instrument; so that equal altitudes may, if possible, be obtained, should noon prove cloudy. These may be worked as double altitudes, by the methods most approved, but treated in the same manner as the equal altitudes on shore, after determining the time as by single altitudes, the latitude may be deduced to great nicety. The following observations will show the system.

At Sea ♄ 12 IX/29.

N.B. Time is reduced by Chronometer to M. T. at Greenwich.

	h. m. s.	Decl.				h. m. s.		
A.M.	18 9 17	4° 17′ 26″	T. alt.	63° 31′ 3″	P.M.	20 17 36.7	Dec. cor.	4° 15′ 24″
Equ. of time		3 44.1					Equ. time	3 46.0
Diff. lat. before noon		0° 3′ 18″ S.	Lat. by Mer. alt.	17° 1′ 54″ S.			Diff. lat. P.M.	0 3 18 S.
Long.	„	6 45 W.				3 18	Long. „	6 45 W.
				A.M. sights	..	16 58 36		
				P.M. „	..	17 5 12		

Erroneous lat. ..... 17° 18′ 36″ = 20′ error. 17° 25′ 12 = 20′ error.

The time worked out with these data—

	h. m. s.			h. m. s.	
Gives M. time	22 54 9.1 A.M.		Gives M. T.	24 57 51.6 P.M.	
M. T. Gh. ..	18 9 17		M. T. Gh...	20 17 36.7	
Long. in time	4 44 52.1 = 71° 13′ 1″.5	70° 3′ 43″.5		4 40 14.9	Long. in time.
Diff. long.	6 45 A.M.	6 45 P.M.			
Red. to noon	71 6 16.5	70 10 28.5 red. to noon.			
P.M. set	70 10 28.5				
Mean noon long. ..	70 38 22.5	by chr., A.M. sights only, 70° 41′ 8″			

Now, taking this *mean* as the true longitude at noon, and applying the difference of longitude to each, we obtain the longitude *at sights*. The longitude, in time, at sights; the equation; and M. T. Gh., as shown by the chronometer; afford the apparent time from noon, as follows:—

	° ′ ″		° ′ ″	
Mean long. noon	70 38 22.5	Mean long. noon	70 38 22.5	
Diff. long. A.M.	6 45.5	Diff. long. P.M.	6 45.5	
At A.M. sights	70 45 7.5	Long.	70 31 37.5	P.M. sights.

	h. m. s.		h. m. s.
M. T. Gh. A.M. by chr.	18 9 17	P.M.	20 17 36.7
Long. in time	4 43 0.5	Long. in time ..	4 42 6.5
Eq. contrary sign	3 44.1	Equ...........	3 46.0
	22 56 1.6	Hour ∠	1 3 29.2
Hour ∠	1 3 58.4		

Now, working each side out, as in former examples, the result A.M.

Gives	16° 57′ 45″		P.M.	17° 5′ 3″
Diff. lat. A.M.	3 18		Diff. lat. P.M.	3 18
		Mean.		
Latitude	17 1 3 noon ..	[17° 1′ 24″] ..	Lat.......	17 1 45 at noon.

Differs 30′ from true, or that observed on sea horizon. Using this latitude, the longitude is readily obtained without a meridian altitude.

Thus, then, this example (as well as numerous others) clearly shows, that even assuming a latitude 20′ in error, the correct latitude and longitude is nearly attained by one operation; but, by repeating it with the latitude thus found, the *probability* is in favour of such being the *true* result, as the horizon is more clearly defined at those periods than at noon.

AZIMUTHS.

The next subject which demands our attention, is the "Variation of the Compass," and in ships not provided with Barlow's Plate, becomes of more importance than is generally supposed; although bad steerage may in many cases be the true evil. The object is to avoid, or correct, all *known* errors. Few naval men, unaccustomed to pursue nautical astronomy, or magnetical experiments, closely, are aware of the true causes of error in dead reckoning, particularly when beating to windward, in the chops of the British Channel.

Current has been seized on to account for large errors; but in those ships where strict attention has been paid to the corrections for local attraction, due to *each course*, no such enormous errors, or currents, have been experienced. The local attraction in the British Channel has been known to amount to 4½ degrees with the head E.S.E., and the same in the opposite direction, at W.N.W., making *nine degrees* local attraction between those two points. Now, if the reckoning be worked on this error, it is not improbable that the allowance for current may be compensated during 24 hours, for it is well established that currents, and tides, do exist there, and have great influence.

Between the Azores and the continent, the variation changes suddenly, about two degrees, which can only be fairly determined by frequent observations. It is a mistaken idea that a ship *must*, of necessity, be very steady to observe an azimuth. In a gale it is difficult, if not impossible; but under strong breezes, and even considerable motion, it is seldom omitted in vessels properly fitted, and using Gilbert's prismatic compass.

The object is to be attained by practice only; and although at first sight the observer fancies the motion of the card sets him at defiance, yet he will very soon perceive that the oscillation has a mean motion, and he can determine to ten minutes, what the middle point is.

Immediately after taking his sights for time, let him go to the azimuth compass, and moving the dark reflector, until he causes the sun's reflected image to be seen just on the graduation, watch when the motion becomes sluggish. He should call "stop," and continue to read off, as rapidly as he can, the mean oscillations; calling stop at the tenth. The following shews the form of taking, and noting, such observations.

☾ 9 VII/$_{32}$ at Sea.

+ P. = with Barlow's Plate; — P. without do.

h. m. s.	° ′	h. m. s.	° ′
8 11 56	86 0	8 12 42	85 00
	85 50		30
	50		30
	30		40
+ P. Head N.	30	— P.	30
	40		20
	40		20
	40		30
	50		40
12 22	40	8 13 8	86 00
Mean 8 12 9	85 43	8 12 55	85 30

Tacked. Head S.E.

h. m. s.	° ′	h. m. s.	° ′
8 35 50	82 20	8 36 38	82 00
	40		00
	30		40
	20		83 00
+ P. Head S.E.	20	— P	0
	30		0
	00		82 40
	00		83 0
	81 40		10
36 14	82 00	37 12	00
Mean 8 36 2	82 14	8 36 55	82 45

With the apparent time, deduced from the altitudes taken for chronometer, the sun's true bearing is obtained, (*vide* page 58,) and thence the variation. If any doubt is thrown on the result, the true bearing may be worked from the altitude, which may be obtained by computation, or by proportion: in the latter case one altitude should be taken by time after the set is completed.

LUNAR DISTANCES.

Before treating on this subject, one of importance to the service in general, it may be well to caution the observer, when taking his distances, to *note* whether his motion on the tangent screw is *progressive* or *retrograde*. The most perfect instruments have a material difference. It is not a bad rule:—"Never make an observation on the retrograde motion." There is always sufficient time, and by this means no confusion of errors can arise. Taking the distances, &c., with three observers, requires little comment. Those who know the value of their own observations prefer taking all themselves.

An assistant, to note the time, is all that is requisite, and he should understand, signals of finger, head, or foot, so as to tell the second, without speaking to him. Thus, suppose the observer can distinctly count the beats of the chronometer; just as the contact is about to *take* place, or he is about to *make* it, he wishes the second; it is named; instead of saying "stop," when his attention may be withdrawn, &c. he states the beat, which is inserted in seconds and parts. (But with a good assistant this may be neglected, as he almost knows the "stop" is coming.) The form will stand thus:—

h. m. s.	☉	☾'s U. L.	☾'s N. L.
8. 10. 20	28° 28′ 50″		
11. 15		64° 20′ 30″	
11. 50			79° 20′ 10″
12. 30			20. 10
12. 50			20. 20
13. 15			20. 20
13. 56			20. 30
14. 20	29. 4. 10		
15. 5		63. 50. 50	

Continuing thus without intermission, at *sets*, until 10 such have been taken, or perhaps 50; the last altitudes of the first, being the first of the second set. They are then to be reduced for work as follows:—

h. m. s.	☉	h. m s.	☾'s U. L.	h. m. s.	☾'s N. L.
8. 10. 20	28° 28′ 50″	8. 11. 15	64° 20′ 30″	8. 11. 50	79° 20′ 10″
14. 20	29. 4. 10	15. 5	63. 50. 50	12. 30	10
				12. 50	20
0. 4. 0	0. 35. 20	0. 3. 50	0. 29. 40	13. 15	20
				13. 56	30
				14. 21	90
				8 12. 52. 2	79. 20. 18

Then, ☉; If 4m. 0s. give 0° 35′ 20″ what will the diff. between 8. 10. 20 and 8. 12. 52. 2 give.
And, ☾; If 3m. 50s. ,, 0. 29. 40 ,, 8. 11. 15 and 8. 12. 52. 2 give.

The results, applied to the upper line, give the altitudes at the instant of the mean of the times of the distances, viz. at $8^h\ 12^m\ 52^s.2$. Consequently it is reduced to the same conditions as if three observers had simultaneously made the observations.

The reduction of the true distance does not come within our limits. That by Thompson's Tables is the shortest, that by Professor Inman more satisfactory, and, if disposed to closer corrections, that by Galbraith most complete. The true distance being found, it is customary to determine apparent time, and thus obtain the longitude. This is no test of the chronometer: because the determination may take place some hours distant; the rate of chronometer, run of the ship, currents, &c. vitiating any such calculations.

Now it must be evident to every practical observer, that his determination by lunar is not that on which he most depends, and that from day to day his observations are founded on the equable rate of his chronometer. Let us then assume that he takes his observations for chronometer at 8 A. M., and determines his longitude; he well knows *that* longitude depends on his computed error on Greenwich mean time. Now, if his lunar distances were observed in the following middle and morning watches, and the sun was not visible after 6 A. M., what reference can he fairly make to the previous day, *perhaps* 20 *hours antecedent?*—None satisfactory.

Let the lunars, then, be made a test for the chronometer on *Greenwich mean time.* Thus: the distances give the *apparent time* at Greenwich, itself a sure element for precisely correcting the equation, from which deduce the *mean time* at Greenwich, and comparing it with that computed by chronometer, call the difference, *error of chronometer on mean time at Greenwich.* Now the rate of a chronometer in 24 hours may hardly be supposed to exceed 15 seconds, and the error of rate, *supposing it changed,* to exceed 2 seconds in that interval, it may safely be assumed then that the longitude is within half a mile.

Example:—At 20 h. on the 1st of August, 1831, the mean time at Greenwich was computed from original rate and error to be, 21 h. 41 m. 10 s. rate + $15^s,5$. The following morning, at 16 h. by chronometer, the means of 10 sets east, and 10 west, of moon and stars, gave the error of chronometer on Greenwich mean time as $17^h\ 41^m\ 30^s,5$.

	h. m. s.	
Then, error at 20 h. 1st August	1 41 10	
Decimal for 1 hour, ,646 × interval 20 h. ..	12.92	(20 — 24 = 4 + 16 = 20)
Mean time at Greenwich by computation.....	1 41 22.92	
————— by lunar	1 41 30.50	
Error by lunar	7.58	

Time elapsed since last error and rate determined = 20 days; then $7^s.58 \div 20 = ,379$, therefore the longitude by chronometer, as determined by preceding day, could not have been in error more than one-third of a second in time. By a continued series of such determinations the values can always be referred to the chronometer *direct*, and a fictitious "*guard rate*" be adopted, without the trouble and liability of error in correcting longitude; and on arrival in port, after establishing its error on landing, its various "*guard rates*" may be referred to, and not only their value ascertained, but our own, as observers. This is important by bringing us to a standard, as to whether we observe too close, too open, &c.; feelings only to be understood by those who entirely devote themselves to such labours. The young observer should not be alarmed at the differences wide of his rates or error. Let him tabulate them.

			New.	
Thus.	1 August.	Old rate $15^s.5$	15.879	
	5 ,,	,,	16.230	
	11 ,,	,,	17.240	
	13 ,,	,,	14.210	
	14 ,,	,,	14.140	
			27.749	
		Mean guard	15.549	not differing much from original.

If practicable, distances on each side of the moon should be obtained at close intervals, and the rising and falling bodies obtained over nearly similar arcs. The altitudes are more safely computed, particularly if on shore, when the apparent time can be obtained from transit, or equal altitudes.

CHRONOMETERS.

Much has been advanced on the subject of chronometers and the determination of their errors at periods intermediate to the times of rating. Let us refer to any tabular sets of comparisons, and it will be evident that no law will embrace every subject. A chronometer is found to commence with a rate of $5^s.0$; for five days it means 4.6; the next three, 6.3; the next seven, 7.2; the next five, 6.0; and next seven, it has perhaps 5.5.

Thus, then. Started at $5^s.0$.	5 days..	4.6
	3	6.3
	7	7.2
	5	6.0
	7	5.5
Days	27	

Now, for seven days it had a rate of 7.2; but to know this is beyond our reach; all that appears is, that between its last determination of error it has such a difference as would increase its rate, if divided by 27, but that previous to starting its mean rate was uniformly 5.0; and since arrival has returned to the *same*.* Those who have had much practice in chronometers, are aware, that they will occasionally, without *change of rate, jump*, or show a difference of two to three seconds for *one day*, and then continue the *previous* rate. Where a large number of chronometers are available, they can be made to check any such disturbances.

The Ætna's establishment had seven government, and three private chronometers, that in which the greatest confidence was placed, being one of the latter, (pocket silver, by Barraud,) and which was subject to constant motion from ship to shore, when in harbour.

The time of winding up was generally 6 A.M. by the standard, or nearly that of Greenwich, thus leaving the whole of the day available for more active duties. At this time all the chronometers were compared, allowing an interval of 30 seconds between each, by which they were all readily reduced to the same instant. Each chronometer was then reduced to mean time at Greenwich by its error and rate, and afforded, at sight, any variation beyond that of its daily difference from the standard.

On Sunday, at *Greenwich noon*, as nearly as the *minute* could be estimated, another comparison was obtained; and by the *mean of the reduced times*, each chronometer was tested as to its week's work. When it became necessary, or opportunity offered, a new error was obtained, and if any material position was involved in doubt, the rates, worked back to the period, seldom deviated from such deduction as these weekly results would have afforded; added to this, it became a record in office, by which doubt, at any future date, could be instantly resolved. The rate, error, &c. standing against every day, and the Sunday noon reductions for standards.

* Very frequently the case.

The following formula being a copy of the performance of the Ætna's chronometers on the 14th day after rating, will clearly show the principle. The comparisons were repeated at 50 sec. and the minute; at 20 sec. and the ½ minute, which afforded ample time for registering, (the formula being previously ruled.)

Comparison of Chronometers, H. M. S. Ætna. ⊙ 20 V/32. Off Bijuga Islands.

Date.	Standard. No. 865	1640	287	943	311	2	665	$\frac{2}{591}$	$\frac{2}{623}$	218
V/32 ⊙ 20	h. m. s. 11.50. 0	h. m. s. 1.19.18	h. m. s. 12.26. 5.5	h. m. s. 11.57. 7	h. m. s. 11.50. 7.5	h. m. s. 1.12.36.5	h. m. s. 12.17.43	h. m. s. 11. 6.36	h. m. s. 12. 6.27.5	h. m. s. 11.11.37
	 30	.. ..	12.26.35.5							
	..51. 0	.. ..	.. ..	11.58. 7						
	 30	.. ..	.. ..	.. ..	11.51.37.5					
	..52. 0	.. ..	.. ..	.. ..	.. ..	1.14.36.5				
	 30	.. ..	.. ..	.. ..	.. ..	.. ..	12.20.13			
	..53. 0	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	11. 9.36		
	 30	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	12. 9.57.5	
	..54. 0	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	11.15.37
Green-wich error.	0. 0. 0.911	0. 0. 0.399	11.59.57.949	0. 0. 1.799	0. 0. 0.885	0. 0. 1.344	0. 0. 1.946	11.59.59.910	11.59.59.179	11.59.56.769
	0.10. 0.911	1.19.17.601	26. 7.551	2.54.799	9.53.385	1.12.35.156	17.41.054	53.23.910	6.28.326	48.19.769

					h.	m.	s.
⊙ 20 V/32.	Thus, then,	865	= standard =		0	0	0.911
		1640	,,		0	0	0.399
		287	,,		11	59	57.949
		943	,,		0	0	1.799
		311	,,		0	0	0.885
		2	,,		0	0	1.344
		665	,,		0	0	1.946
	Pocket .	$\frac{2}{591}$	,,		11	59	59.910
		$\frac{2}{623}$	,,		11	59	59.179
		218	,,		11	59	56.769
							1.091
	M. T. Greenwich by chronometers				0	0	0.1091

Now, it is apparent that 287 and 218 are going astray, but as they were found to do so frequently, and not to adhere to an *uniform* increase, or decrease, they were generally rejected, when their errors exceeded four seconds.

It hardly requires explanation, that the line of times after 1640, is obtained, by subtracting 30 seconds from 287; 1 minute from 943; 1.30 from 311; &c.

Subsequently, the chronometers were subjected to severe trial by the shocks the ship received, riding heavily off the Bijuga shoals, so much so, as to part the shank of small bower, and coasting and stream cables. Yet even after all this, they were found, on arrival at the Gambia, on the 13th of the following month, to give the longitude of St. Mary's within 3″.57 of the truth. Chronometers should be placed as low down in the ship as convenient, and between the main and mizen masts, amidships. They are affected by local attraction, and should, therefore, if possible, occupy the central line of any such affection. Captain Scoresby and others have proved, that they are sensibly affected by magnets, and that the change in position will materially affect the rate. It has, therefore, been the practice to keep them always in the same *relative* position, with regard to each other.

The operation of winding up in bad weather is difficult, being compelled to take care of one's-self, preserve the chronometer steady, and continue the motion of winding. It is to be regretted that the box chronometer is not furnished with the means of performing this without disturbing its position; and it is the more extraordinary, as the adaption of a spindle on the side is so simple, that one cannot imagine why

it has been so long neglected. The aperture would thus be securely closed from the dust, and the jerk but too frequently occurring, by slipping through the fingers, when the key is withdrawn, entirely obviated.

We have now observed on the practical use of such instruments as may always be met with in every ship of war. For minute details of superior instruments, and full directions for their treatment, the reader must refer to more voluminous works—to that of Dr. Pearson's Astronomy in particular.

PORTABLE TRANSIT AND ALTITUDE INSTRUMENTS.

The portable transit, azimuth and altitude instrument, will require some few observations, as coming immediately within the range of the marine surveyor. A good theodolite may also be rendered available; indeed, where the mind is intent on deriving the utmost value from the instruments at hand, difficulties soon disappear.

The determination of the latitude by the altitude instrument, or theodolite, is easily performed. Determine the error of the watch on apparent time by morning sights, with the sextant and artificial horizon. Take out from the Nautical Almanac the time of the sun's semi-diameter passing the meridian, and subtract it from the computed *apparent noon* by chronometer. At ten minutes before noon, being either upper or lower limb of the sun to the horizontal wire; note the time, and read off the altitude; repeat this at five minutes; then watch the meridian passage, the assistant calling the beats up to the computed time of the limb's contact. Read off the azimuth and altitude. Set the instrument to the altitude it had at five minutes before noon, and follow the sun with the telescope, until it falls to it. Note the time; then set it to the altitude corresponding to ten minutes before noon, and note also the time it arrives at the same. The meridian altitude, and four circum-meridian distances, are thus obtained.

With apt observers, the circum-meridian distances would commence fifteen minutes before, and terminate fifteen minutes after, noon; comprising about ten distances, and their corresponding times. The azimuths at first, centre, and last, when taken so rapidly,

afford the approximate meridian, and by a theodolite, with needle attached, the variation.

Chronometers may be rated by a theodolite, by making use of *one* star nightly; as the vertical motion *at* its meridian altitude will not be liable to derangement, if the instrument be devoted *solely* to this use; and it is not of material consequence that it should be in the meridian, as the *rate* would be the only term required. The result would be its rate on sidereal time, which, by the subtraction of $3^m\ 55^s.91$ is readily reduced to solar.

The wires of a theodolite are easily illuminated by affixing a piece of paper at the object end, and causing it to bend obliquely towards the line of vision, but not to obstruct more than *one-fifth* of the field, and on the western side; a ray from a candle or lamp, directed on the paper, will answer the purpose effectually.

By placing an altitude instrument, or first-rate theodolite, nearly in the meridian of a transit, a series of observations may be obtained in one night, both off, and in the meridian, which may satisfactorily determine the position in latitude. The stars may thus be made subservient during the whole night, and serve to fill up the interval when a long period occurs between the transits.

Observations in the meridian may be multiplied by placing an artificial horizon before the instrument, (adjusted by depressing the telescope the same number of degrees as the computed altitude.) The altitude direct may be read off at the second wire, and the double altitude, by reflection, obtained nearly in the meridian, by which the errors are removed.

The valuable work of Dr. Pearson, on Practical Astronomy, has been already mentioned, but the following extract so clearly bears on our subject, that no apology is necessary for its insertion here.

"When the portable altitude and azimuth circles are used out of the meridian, in a state of proper rectification, they are peculiarly adapted for giving, at the same instant, such measures as constitute the ground-work of various computations; and on this account, as well as by reason of the transits that may be taken in the meridian, these instruments, considered as portable instruments, are peculiarly useful in voyages, or travels of discovery, where a solid rock will supply the place of a pedestal, or firm tripod, on any shore, or place, that may be accessible."

[A 32, or 40 gallon cask, sunk into the earth to the bung-hole, filled with sand or water, and the earth well beaten round its sides, forms a very convenient stand for the transit, or this instrument.]

"When the daily rate of a clock, or chronometer, is required to be determined, without reference to the *absolute* time, it will not be necessary to regard either the exact altitude, or azimuth, of the star to be observed; for Mr. Riddle has shown, that if the exact times be noted when the star has the *same altitude* on successive days, either in the eastern or western hemisphere, by a clock or chronometer going equably, the differences of the observed times, separately compared with 3 m. 55s. 91, the star's gain in a sidereal day, will give the loss or gain of such solar clock or chronometer.

"On whatever part of the globe the traveller may have occasion to place his instrument, there are always three points of reference in the heavens with which his observations are connected, viz.

"The upper pole of the equator = P.

"The meridian zenith of his place = Z.

"The point apparently occupied by the star or body observed = S.

"The meridian line in the heavens connects the pole and zenith; a circle of declination the pole and star; and a vertical, the star and zenith; hence a triangle, which may be denominated the *astronomical triangle*, is always formed by the three lines, P Z, P S, and Z S, which represent respectively, the colatitude of the place, λ; the polar distance of the body observed, Δ; and the zenith distance, z.

"If we call the horary angle formed at the pole, h; the azimuthal angle formed at Z, a; and the angle of variation formed at S, v; then, when any three, out of the six parts of the spherical triangle, are given by the instrument and chronometer, or clock, the other three may be computed from the following formulæ, which afford several varieties of interesting deductions, where ϕ is introduced in some of the more complex cases as an auxiliary arc or angle, to simplify the formula and to adapt it for logarithmic computation."

Table of Formulæ from Dr. Pearson's Astronomy.

No.	Given.	Reg.	Aux. Angles.	Formulæ.
1	z Δ λ	h	....	$\text{tan. } \tfrac{1}{2} h = \frac{\text{sin } \frac{1}{2}(z + \Delta - \lambda) \text{ sin. } \frac{1}{2}(z + \lambda - \Delta)}{\text{sin. } \frac{1}{2}(z + \Delta + \lambda) \text{ sin. } \frac{1}{2}(\Delta + \lambda - z)}$
2	Δ λ a	h	$\text{tan. } \phi = \frac{\text{cot. } a}{\text{cos. } \lambda}$	$\text{cos. } (h \backsim \phi) = \frac{\text{cot. } \Delta \text{ cos. } \phi}{\text{cot. } \lambda}$
3	z λ a	h	$\text{cot. } \phi = \frac{\text{cot. z}}{\text{cos. } a}$	$\text{cot. } h = \frac{\text{cot. } a \text{ sin. } \lambda \backsim \phi}{\text{sin. } \phi}$
4	z Δ a	h	....	$\text{sin. } h = \frac{\text{sin. z sin. } a}{\text{sin. } \Delta}$
5	z Δ λ	v	....	$\text{tan. } \tfrac{1}{2} v = \sqrt{\frac{\text{sin. } \frac{1}{2}(\lambda + z - \Delta) \text{ sin. } \frac{1}{2}(\lambda + \Delta - z)}{\text{sin. } \frac{1}{2}(\lambda + z + \Delta) \text{ sin. } \frac{1}{2}(\Delta + z - \lambda)}}$
6	Δ λ a	v	....	$\text{sin. } v = \frac{\text{sin. } \lambda \text{ sin. } a}{\text{sin. } \Delta}$
7	Δ z a	v	$\text{tan. } \phi = \frac{\text{cot. } a}{\text{cos. z}}$	$\text{cos. } v \backsim \phi = \frac{\text{cot. } \Delta \text{ cos. } \phi}{\text{cot. z}}$
8	z λ a	v	$\text{cot. } \phi = \frac{\text{cot. } \lambda}{\text{cos. } a}$	$\text{cot. } v = \frac{\text{cot. } a \text{ sin. (z } \backsim \phi}{\text{sin. } \phi}$
9	Δ λ h	v	$\text{cot. } \phi = \frac{\text{cot. } \lambda}{\text{cos. } h}$	$\text{cot. } v = \frac{\text{cot. } h \text{ sin. } (\Delta \backsim \phi)}{\text{sin. } \phi}$
10	Δ z h	v	$\text{tan. } \phi = \frac{\text{cot. } h}{\text{cos. } \Delta}$	$\text{cos. } (v \backsim \phi) = \frac{\text{cot. z cos. } \phi}{\text{cot. } \Delta}$
11	z λ h	v	....	$\text{sin. } v = \frac{\text{sin. } \lambda \text{ sin. } h}{\text{sin. z}}$
12	z Δ λ	a	....	$\text{tan. } \tfrac{1}{2} a = \sqrt{\frac{\text{sin. } \frac{1}{2}(\Delta + \lambda - z) \text{ sin. } \frac{1}{2}(\Delta + z - \lambda)}{\text{sin. } \frac{1}{2}(\Delta + \lambda + z) \text{ sin. } \frac{1}{2}(z + \lambda - \Delta)}}$
13	Δ λ h	a	$\text{cot. } \phi = \frac{\text{cot. } \Delta}{\text{cos. } h}$	$\text{cot. } a = \frac{\text{cot. } h \text{ sin. } (\lambda \backsim \phi)}{\text{sin. } \phi}$
14	z λ h	a	$\text{tan. } \phi = \frac{\text{cot. } h}{\text{cos. } \lambda}$	$\text{cos. } (a \backsim \phi) = \frac{\text{cot. z cos. } \phi}{\text{cot. } \lambda}$
15	z Δ h	a	....	$\text{sin. } a = \frac{\text{sin. } \Delta \text{ sin. } h}{\text{sin. z}}$
16	z Δ a	λ	$\text{tan. } \phi = \text{cos. } a \text{ tang. z}$	$\text{cos. } (\lambda \backsim \phi) = \frac{\text{cos. } \Delta \phi}{\text{cos. z}}$
17	z Δ h	λ	$\text{tan. } \phi = \text{cos. } h \text{ tan. } \Delta$	$\text{cos. } (\lambda \backsim \phi) = \frac{\text{cos. z cos. } \phi}{\text{cos. } \Delta}$
18	z a h	λ	$\text{cot. } \phi = \frac{\text{cot. z}}{\text{cos. } a}$	$\text{sin. } (\lambda \backsim \phi) = \frac{\text{cot. } h \text{ sin. } \phi}{\text{cot. } a}$
19	Δ a h	λ	$\text{cot. } \phi = \frac{\text{cot. } \Delta}{\text{cos. } h}$	$\text{sin. } \lambda \backsim \phi = \frac{\text{cot. } a \text{ sin. } \phi}{\text{cot. } h}$
20	z λ a	Δ	$\text{tan. } \phi = \text{cos. } a \text{ tan. z}$	$\text{cos. } \Delta = \frac{\text{cos. z cos. } (\lambda \backsim \phi)}{\text{cos. } \phi}$
21	z λ h	Δ	$\text{tan. } \phi = \text{cos. } h \text{ tan. } \lambda$	$\text{cos. } (\Delta \backsim \phi) = \frac{\text{cos. z cos. } \phi}{\text{cos. } \lambda}$
22	z a h	Δ	....	$\text{sin. } \Delta = \frac{\text{sin. } a \text{ sin. z}}{\text{sin. } h}$
23	λ a h	Δ	$\text{tan. } \phi = \frac{\text{cot. } a}{\text{cos. } \lambda}$	$\text{cot. } \Delta = \frac{\text{cot. } \lambda \text{ cos. } (h \backsim \phi)}{\text{cos. } \lambda}$
24	Δ λ a	z	$\text{tan. } \phi = \text{cos. } a \text{ tan. } \lambda$	$\text{cos. (z } \backsim \phi) = \frac{\text{cos. } \Delta \text{ cos. } \phi}{\text{cos. } \lambda}$
25	Δ λ h	z	$\text{tan. } \phi = \text{cos. } h \text{ tan. } \lambda$	$\text{cos. z} = \frac{\text{cos. } \lambda \text{ cos. } \Delta \backsim \phi}{\text{cos } \phi}$
26	Δ a h	z	....	$\text{sin. z} = \frac{\text{sin. } h \text{ sin } \Delta}{\text{sin. } a}$
27	λ a h		$\text{tan. } \phi = \frac{\text{cot. } h}{\text{cos. } \lambda}$	$\text{cot. z} = \frac{\text{cot } \lambda \text{ cos. } (a \backsim \phi)}{\text{cos. } \phi}$

The nicety required, in the observations alluded to by Dr. Pearson, can only be attained by first-rate instruments; therefore these observations will refer principally to such as the young observer may happen to have the use of; at the same time observing, that if the same microscope be used on the superior azimuth and altitude instrument, and the altitudes be correctly reset, a complete series can be made on all the stars available, and the delicacy required be met by the accumulation of data. Note the first star which will pass the meridian after twilight, or when observation commences on these bodies. Refer to the catalogue three hours in advance, (by right ascension,) and find what stars in succession will least interfere with meridional times of transit, and also be available for equal altitudes. Take three careful observations of the star, noting the times, altitudes or zenith distances, and readings on the azimuth plate. The times of meridian passage will furnish the times when the same bodies will arrive at corresponding altitudes past the meridian; when the instrument being carefully set by the same vernier, microscope, &c. note the times and azimuth corresponding to these equal altitudes.

Now, if the transit be in use, and the instrument placed at a convenient distance in its meridian, or nearly so, this serves as a meridian mark. Thus, direct the telescope of the transit to the *axis* of the altitude instrument; unscrew the eye piece, and place a light behind it, (the reading-off lamp.) Look down the throat of the transit with the telescope of the altitude instrument, and, by the tangent screw on the azimuth plate (of the altitude instrument) cause the wires of both to coincide. [This results from the rays of light passing through the object-glasses of both telescopes being *parallel.*] This then is the meridian, and is to be taken as the zero from which the azimuths referred to, in previous observations, are to be reckoned. Or, by two observers; note the passage of the star over the wires of each instrument; causing the star to bisect the centre wire of both at the same instant, (by following its motion with the tangent screw of the altitude instrument, until the observer at the transit calls "*stop*," counting up the *known* half seconds, until contact; this affords a value to the motion of the screw, which renders the task simple.)

The time, latitude, or azimuth, may then be deduced from the formulæ, which will be rendered more intelligible by the following examples.

Example.

(*From Pearson's Astronomy.*)

May 28, 1828.—Given, the zenith distance of α Aquilæ, corrected for refraction $=65^{\circ}\ 18'\ 45''$, and its corresponding azimuth (by instrument) from the N. point $= 109^{\circ}\ 27'\ 43''$, to determine the hour angle, and Latitude.

By Naut. Alm. 1828, the App. N. pol. dist (Δ) of, α Aquilæ $= 81^{\circ}\ 34'\ 39''$, and its R. A. 19h. 42m. 26s. neglecting fractional parts; so that we have the three parts, z, a, and Δ, as data for determining the postulata, by 4 and 16 of formulæ.

Formula 4. $\sin. h. = \dfrac{\sin. z. \sin. a}{\Delta}$

Sine of z = zenith dist. of α Aquilæ $65^{\circ}\ 18'\ 45''$ log.	9.9583724
Sine a = azimuth of body $109^{\circ}\ 27'\ 43''$	9.9744486
Sum....	19.9328210
Sine Δ = N. pol. dist. of α Aquilæ $81^{\circ}\ 34'\ 49''$ = ...	9.9952906
Sine $h = 60^{\circ}\ 0'\ 0''$ hour angle....	9.9375304

	h. m. s.	
Or, ...	4. 0. 0	sidereal time.
Star's R. A.	19.42.26	
Diff.	15.42.26 = h if in the east.	
Sum	23.42.26 = h if in the west.	

Next, for latitude.

Formula No. 16. $\cos. (\lambda \backsim \phi) = \dfrac{\cos. \Delta. \cos. \phi}{\cos. z.}$ and aux. ang. tang. $\phi = \cos. a$, tang. z.

Cos. a. = azimuth of body $109^{\circ}\ 27'\ 43''$....	9.5226798
Tang. z. zen. dist. $65^{\circ}\ 18'\ 45''$........................	3.3375408
Tan. ϕ. $-35^{\circ}\ 56'\ 5''$ Sum....	9.8602206
Then cosi. Δ $81^{\circ}\ 35'\ 49''$ N. P. D. of star	9.1657531
Cosi. ϕ $35^{\circ}\ 56'\ 5''$..................................	9.9083167
Sum	19.0740698
Cos. z, $65^{\circ}\ 18'\ 45''$ Z. D. of star	9.6208321
Cos. $(\lambda \backsim \phi)$ $73^{\circ}\ 30'\ 15''$ ....=	9.4532377
Add ϕ 35.52. 5	

$\lambda =$ 37.34.10 or lat. $= 52^{\circ}\ 25'\ 50''$

As the polar distances of the stars are now given in the Nautical Almanac, the next example (deducing the polar distance from the time observed) has not been introduced.

The true meridian has been supposed to be determined from the transit, but it is obvious, that by using the instrument for equal altitudes, the middle point between the readings in azimuth must be nearly the meridian, and to such it may be safely referred for meridian zenith distances, until the determination of the time by equal altitudes affords a better test, by the transit of the first star following such computation.

The following method, described by Professor Bessel, is also worthy of attention, and may be readily practised with an azimuth and altitude instrument, when not used for the purpose of a transit.

By the azimuth plate, point the telescope true east and west; select a star near the zenith,* and observe its passage over the wires, east and west. [This may be repeated on other stars.]

Then. To the log. tang. of the star's N.P.D. add the log. cosine of half the elapsed time; the sum, rejecting tens in the index, will be the log. tang. of the co. lat. sought. This method is convenient, and if the motion of the instrument be perfect, independent of graduation.

The transit, azimuth transit, or theodolite used as such.

It should be borne in mind that the object of the transit instrument, or that substituted, is to obtain a truly vertical motion in the meridian; and to observe the passages of heavenly bodies over the wires of the telescope, by which either sidereal or solar time is obtained.

When the sun is the body, the time is apparent solar, his passage being 0h. 0m. 0s. which by the application of the equation of time, with its proper sign, is reduced to mean solar.

As the principal object to the surveyor is the rating his chronometers, and he seldom has a clock, (or time to establish his observatory,) it will be referred to that motion. The reduction to sidereal, when required, is readily performed by tables for that purpose.

On landing, the first object of the surveyor is to obtain the true time; this cannot be more satisfactorily determined than by equal altitudes. He may, however, by knowing the latitude very nearly, work

* By making use of the star near the zenith, the interval is less, and rate of chronometer less important.

several of his A.M. sets, and obtain an approximate error, by which he may be enabled to give a fair direction for the meridian; and if an azimuth transit, obtain his latitude.

Thus, having determined his error on apparent time, on 1 Aug. 1834, to be $1^h\ 0^m\ 41^s.5$ he will refer to the Nautical Almanac, page I of the month, and take from thence the sidereal time of the semidiameter passing the meridian $= 1^m\ 6^s.60$. which is reduced to mean time by the subtraction of $0^s.18 = 1^m\ 6^s.42$. Now, as the western limb touches the centre wire at this interval before noon; by subtracting this quantity from the computed apparent noon, he will obtain the time at which the first, or western limb, makes the contact $= 0^h\ 59^m\ 35^s.08$. By adding the same quantity, he also obtains the eastern contact, by which, if he be doubtful of the accuracy of his first, he is enabled to rectify his mistake. The instrument then having a *direction*, he proceeds to bring it into the minutest adjustment of which it is capable, by the levels, taking care to erect a meridian mark, or to find some distant object, north or south, at nearly the same level, to which he can ultimately refer his wires, as the slightest adjustment may otherwise throw him out of the meridian.

Now, it should be borne in mind, that a transit instrument merely requires a true vertical motion in the plane of the meridian.

The axis then must first be adjusted, which is determined by the "riding level." Precaution.—Examine the Ys, and see that they are free from dust. Also, examine the ends of the axis, and wipe them clean. The slightest grit would materially injure the motion, as a rough surface would be produced: and as the instrument is adjusted horizontally, this might not be brought into play until a vertical position be given. All instruments which reverse on their axes should be provided with caps to protect the axes and Ys.

First, level the axis by the "riding level," then suspend a plumb-line (of silver wire) in the meridian,* with the weight immersed in water, (by tripod as before directed,) and place an artificial horizon between

* To give a plumb-line of this nature motion in azimuth (as *apparent* to the observer,) cause the upper loop to lie in the hollow of the thread of a long screw, (which may be purposely fitted for such work, in a shackle, the pin being the screw;) an assistant can then, by giving the screw a slight motion, bring it to coincide with the centre wire. I have a meridian mark constructed on this principle, the motion (horizontal or vertical) being given by fine lines working over disks, which are the nuts of the screws. The observer himself is then enabled to adjust the mark, which is illuminated by night.

it and the instrument, so that the plumb-line can be reflected; another may be placed in the opposite meridian. Observe the lines direct, and then their reflected images. Form in the mind the measure of half this deviation between the direct and reflected images; invert the axis, and repeat the observation: then, bringing the instrument level, correct this by the adjusting screw, which gives motion *vertically*, as the error is caused by the circle described, cutting obliquely to the true vertical passing through the zenith. When the estimated distance is obtained, try if this is equally in error when reflected, or if any further adjustment must be had before moving the suspended wires. Then cause the wire plumb-lines to agree again with the centre wire of the instrument—try if the images coincide. This must be repeated until they do. This levelling of the axis, is generally performed by the "riding level." Thus, first placing it on the ends of the axis, observe where the extremities of the bubble cut, and note them; reverse it end for end, and again note them—find the difference. Half this is the error, to be reduced by the vertical adjustment on the end of the axis. If the level should be defective, much delay ensues, and therefore the former method, as confirming the actual motion, was previously introduced. The riding level itself is so light that the slightest dust (or more frequently corrosion) militates against accurate results on small instruments, and it very frequently occurs, that after reading a level, and again agitating it, or causing it to play over its resting* points, it is found, from having removed dust, or other obstruction, to afford a different result. The sun's rays frequently produce similar defects, from unequal expansion.

If the level, after the former adjustment, disagrees, and the instrument reversed on its axis be found still to bisect the wire, direct and reflected, both north and south, then, and not before, it is time to examine and correct it. The level is furnished with an adjusting screw at one end. Note the readings with its face each way; half the sum of the difference is the error, which is to be corrected by the screw, until the readings each way are brought to coincide.

But it may happen that the centre wire is not truly placed, and all the adjustments will therefore bid us defiance; but this cannot be the

* It has often occurred to me that if fine stationary points arose from the *Ys themselves*, and the level was furnished with jewelled caps at the ends, on which it would rest like a compass card, a proof would be afforded which would point out any *foreign* affection of the *axis*, as, whatever the diameter, the central line of bearing would be the same.

case if the instrument, direct and reversed on its axis, continues to bisect the same object.

If, therefore, after having levelled the instrument by the riding level, and found the readings of the level itself perfect, it still shows a deviation on reversing the axis, the central wire is to suspected.

The wires are placed in a diaphragm, which is a perforated disk, and may be observed in all common telescopes within the tube next the eye. This diaphragm, in theodolite and transit instruments, is moveable by adjusting screws, placed near the eye-end of the telescope. The wires in the transit or first-rate theodolites, are termed the "system," and generally comprehend five vertical and one horizontal. To correct the deviation, or error of centre, a mental value, as before, must be formed for half the deviation observed, and giving the diaphragm an opposite motion, (where the telescope reverses,) and by frequent testing, as before directed, the true position is at length attained. The meridian is next to be found.

The transit instrument has but small range of motion in azimuth, but the instrument being placed as previously directed, it has enough to answer all the purposes required; taking care that the Y be in the centre of motion, before further adjustment is made; in fact, to bring the question more familiarly home to the student, that he may not find his "tangent screw up," (as applied to the sextant,) when he wants further motion. This, to a practised observer, would never occur, but it is our duty to foresee all difficulties, and, if possible, guard against them, feeling some affection for valuable instruments, and knowing that young hands may, by straining the screws, ruin them, and perhaps condemn them as faulty.*

The above adjustments being completed, the original mark, noted after the noon observations, referred to, the instrument is to be again tested on it, and time accurately determined, by the series of equal altitudes; it is now necessary to prove the instrument by the stars during the night.

Compute the transits and zenith distances of all the stars for the night, and look out five minutes before the time of the first passage, taking care that the lamp be lighted and adjusted, and that the zenith distances, or altitude, be on the finder, or altitude circle of the in-

* This arises from having had instruments supplied, which evidently had been so strained, and had been repaired by other hands than the *maker*. Being a practical workman this observation may be excused.

strument. The "finder" on the transit, is a graduated circle attached to the telescope and furnished with a spirit level on its radius or index. By setting the altitude, or zenith distance, the telescope is merely moved until the bubble centres, or shows level. This is of very great importance, when two stars in opposite meridians follow so closely that a few seconds only are allowed, or even that the three centre wires only can be read at each. Thus, by setting the finder at the *second* star, the instrument is immediately brought to its position.

Having the true time, as determined from equal altitudes, and having reduced the star's transit to mean time, apply the correction to the time by watch, taking its rate into the computation, for two stars north, and two south. Watch the star's entrance, which will be apparent on the opposite side of the field, as the telescope inverts. When it has passed the second wire, let the assistant count the ten *beats* previous to the *computed* centre wire, and keeping the hand on the screw which gives motion in azimuth, cause the wire to bisect the star at the tenth beat. Pursue the same with the opposite star, which, if in adjustment, should agree.

Now, it may happen that the instrument is defective, that accident has injured some of the points of adjustment, and that the observer may be induced to discard it from this cause. He should bear in mind, however, that a faulty transit may yet be superior to second-rate instruments, and consider what its defects may be. If the fault be a bend, and the instrument still firm, and *true* to its *faulty* motion, then it may be equally available for his purpose, with some slight addition to his calculations. The instrument will always describe the same curve, although not truly vertical, and therefore, taking the transit of stars *individually,* from night to night, their differences of transit, as before remarked, will afford the rate on sidereal time. The error on mean time can be daily deduced from the sun, and compared with the last preceding morning, and first succeeding evening star. For observations connected with moon culminating stars, the error can hardly affect it. To the observer who is ever ready to make the most of his instruments, it will always occur, that he can make such a *series* of observations as will eventually bring him nearer the truth than indifferent observers with the most perfect instruments.

For all the purposes of *rating* chronometers, the system by equal altitudes, if duly attended to, is as perfect as can be wished; but in every operation of this nature, neither time, labour, or exposure, should be spared.

The object of this treatise being merely the induction to the principal duties, which must ultimately be brought to the closest investigation by the more advanced surveyor,* a brief outline only of the material problems will be given. To those inclined to seek for a more intimate acquaintance with the subject, the works of Dr. Pearson and others will fully meet all they require. It is to be regretted that the observations and illustrations of such authors are so exclusively confined to the higher latitudes, more particularly that of Great Britain, so that those who are seeking such information, for the first time, within tropical bounds, do not meet with a fair solution of their difficulties.

The first requisite problem is the determination of the deviation from the vertical plane. The methods commonly recommended are by circum-polar stars; or of two, differing considerably in declination, usually denominated, "high and low stars." It must be evident that the method by circum-polar stars is soon beyond the reach of the traveller in tropical regions, and in the southern hemisphere we have not sufficient data (although we may shortly hope for it) for making use of those stars which are suited.

The difference of transit, above and below the pole, is equal to twelve *sidereal* hours; and, therefore, we can readily detect, if we know the rate of the watch on sidereal time, whether the period in which this half-circle is described, is greater or less than this quantity. If the interval on the western motion is greater than that of the eastern, then it follows, that the instrument is directed to the eastward of the plane of the true meridian, and does not truly bisect the circle in which that star moves, as the difference of times clearly exhibits greater and less segments;—the error is to be removed by a portion of azimuthal, or horizontal arc, equal to this difference; the motion being in the *direction* of the *excess*.

The simple rule, freed from algebraical form, is as follows:— The data being the latitude; polar distance; and the deviation, or the difference between twelve hours of the motion on either side of the meridian.

To the log. of the half difference of interval in seconds, add the secant of the latitude, and tangent of the star's polar distance, the sum, rejecting tens in the index, will give the log. of the deviation.

If an instrument having azimuthal motion be used, this may im-

* In using the term "surveyor," it is to be taken in its literal sense, as applicable to all who pursue the study.

mediately be applied by turning this quantity into arc, (by multiplying by 15,) and the adjustment made.

If the values of the wires be known, then the error may be applied to the *remote* wires, (taking the precaution to preserve the meridian mark of the previous direction until a satisfactory result is obtained,) and thus correct the deviation by the first, and second, before the centre becomes involved.

By "high and low stars."—Look out in the catalogue two stars, which differ least in right ascension, and about 40° or more in declination, (and which, of course, are to meet the question, being high and low stars for the latitude in which you may be situated.)

We cannot do better than introduce, in full, two examples from the work of Dr. Pearson.

Let the observations, then, apply to the passage of β Aurigæ and Sirius on the 10th Jan. 1828, in lat. 52° 26′ N.

	h. m. s.		h. m. s.
β Aurigæ	5.46.51.91	App. A.R.	5.46.53.50
Sirius	6.37.25.66	„	6.37.33.66
Diff. times	50.33.75	Diff. in A.R.	50.40.16
Diff. A.R.	50.40.16		

+ 6.41 = Diff. times − Diff. A.R.

	m. s.		
Then	6.41	log. of the difference of times —diff. A.R.	0.80686
Add	45° 5′	sine of polar distance β Aurigæ	9.85011
„	106.29	„ Sirius	9.98177
„	52.26	lat. secant	0.21490
„	61.24	sum of declinations, cosec. ar. co.	0.05652
		Arc 2′ 1″,97 = 8ˢ,131 =	0.91016

Again. On 11 October, 1823, the observed transit of α Piscis Austrini, and β Pegasi, were as follows, the times of passage only being given.

	h. m. s.		h. m. s.
A.R. of β Pegasi	22.54.22.26	Observed time (sidereal)	22.54.17.8
„ α Piscis	22.47.55.90	„ „	22.47.51.5
	6.26.36	Diff. times	6.26.3
		A.R.....	6.26.36
		Diff......	0.06

Then diff. times — A.R. = $0^s.06$ .... log.	8.77815
Sine pol. dist. 120° 33′ (or cosi. dec. 59° 27′) α Piscis......	9.93509
,, 62.53 (cosi. dec. 27. 7) β Pegasi....	9.94943
Cosine lat. 52°26″ ar. comp. = secant....................	0.21490
Sine diff. dec. 57° 40″ ar. comp. = cosec..................	0.07317
Arc. 1″,335 — 0^s,089 log. =	8.95074

The rule then will stand thus. From the difference between the times of observation (in sidereal* time) take the difference between the Right Ascensions of the stars, applying the sign + when the lower star precedes the upper, and — when the upper precedes. Now, if the difference between the observed times of passage be exactly equal to the difference of the right ascensions, the instrument will necessarily be in the meridian, supposing the adjustments perfect; if a difference exists, there must be a deviation, which is thus to be computed:

To the log. of the difference between the times of observation and R A. of the stars, add the log. sines of their polar distances, (or cosines of their declinations;) the log. secant of the latitude, and the log. cosecant of the sum or difference of the polar distances—diff. when both are above, sum when on opposite sides of the pole; the sum will be log. of the deviation in azimuth.

In the first example, the deviation is $8^s.131$ seconds of time, or 121″, 97 of arc, from the south towards the east; the instrument must therefore be moved this quantity (by this observation) to bring it into the meridian.

By the second, as the difference in right ascension is greater than the observed difference of transit, the difference is — and the deviation in arc at the horizon = — 1″, 335, was therefore to the west of the true southern meridian, and required this adjustment.

The values of the wires, that is, their distances asunder in motion, should be determined: this is termed the equatorial interval, and is only to be accurately obtained by a series of close observations.

To determine the equatorial interval. To the log. of the interval which the star takes in its motion between *any* of the side wires, to, or from, the *centre*, add the log. cosine of its declination; the sum, rejecting tens in the index, will equal the log. of the equatorial interval.

The values of the equatorial intervals being known, the reduction

* If a chronometer is used, the interval must be reduced to sidereal time by the tables for that purpose.

to the centre, in the event of clouds obscuring the object at the passage, is to be determined thus:—

To the log. of the equatorial interval add the log. secant of the stars' declination, the sum, rejecting tens in the index, equals the log. of the interval to the centre wire: + preceding, and — following wires.

This is also material, in the event of the wires being injured by accident,—the observer may also be so situated that the assistance of an optician cannot be obtained.

Under such circumstances, he may endeavour to remedy the defect himself. Provide a piece of wire about 9 inches long, and bend it to the shape of a horse-shoe magnet, or tongs, allowing a distance of two inches at the horns. Watch a spider, and endeavour to make him pass over the tongs, so as to take up his web: pressing the points gently together, wind off several turns. Now the pressure being removed, the expansion of the tongs will bring a sufficient strain on the web to bring it tight. Lay the diaphragm on a piece of black or coloured paper; apply a touch of copal varnish with a brush on the sides where the web is to be placed, and with the tongs gently place the web on the marked lines, pressing down on the diaphragm until it breaks the web, which will then remain firmly fixed. Each wire* may be thus replaced. Fine silk fibre is used by some opticians, and this should be supplied with all instruments purchased from them.

TRANSIT FORMULA.

The object of the formula used for registering transits in fixed observatories, requires no comment here; but it may perhaps be remarked, that they do not meet all that is required in the temporary observatory, that introduced on the following page will be found not only convenient at the moment, but it becomes of value for future reference.

The *intention* to land and erect the observatory must be supposed, and also that this will occur at a specified date. The bustle of landing, taking observations for time by equal altitudes, erecting tents, fixing pedestals for instruments, and their adjustment, &c. &c., will fully occupy the time and attention of the principal and his assistants;

* They are termed spider lines in great instruments.

and probably night overtakes him before tables, materials, &c. can be conveniently used to make the necessary computations.

OBSERVATORY, DOCK YARD, GIBRALTAR. IX/32.

Date.	Character.	Computed Z. D.	Observed Z. D.	Computed passage by chron. $\frac{2}{591}$	I.	II.	III.	IV.	V.	Reduction of wires.	Barometer.	Therm.	Reduced Latitude.
♂ 4	⊙ 16 WL	29°.16′.0″	29°.16′.30″	h. m. s. 11. 1.52	m. s. 0.49	m. s. 1.22.5	h. m. s. 23. 1.52	m. s. 2.24.5	m. s. 2.55.0	h. m. s. 23. 2.56.85	30.11	85°	36°. 7′.17″
	E.L.		16.50		2.58	3.31	4. 0	4.33	5. 3.5				
	β Cephei.	33.43 N.	33.41.41 42.00	9.38.48	lost.	37.37	9.38.47	39.57.5	41.54	9.38.47.166			36. 7.24

These points then are met by the formula, which may be carried on from day to day until landing is effected. The zenith distances are computed; the intervals between each star reduced from sidereal to

mean time ; and when the result is at length deduced from equal altitudes, the computed times of transit are placed against each star. Or, they may, by the known value of the chronometer, be readily computed beforehand on its rate and error ; as the minute is sufficient warning to look out for the star entering the field ; the error on the first transit affording a value on all the consecutive. The times and zenith distances are thus freed from the error which may result from hurry and fatigue ; and the observed zenith distances being inserted in the proper column, are available at any subsequent period, and not likely to be mistaken.

Such then is the formula adapted for (if the term may be used) flying observatories.

The common method of reduction is, to add together the times, and divide by the number of wires, but the method recommended by Dr. Maskelyne, (and given in Dr. Pearson's work,) when *five wires* are used, materially simplifies the operation.

By the common method—

	h.	m.	s.			h.	m.	s.	
I. wire	23	0	49	1st limb W.		23	2	58	2nd limb E.
II.		1	22.5				3	31	
III.		1	52				4	00	
IV.		2	24.5				4	33	
V.		2	55				5	3.5	
		9	23				20	5.5	
Mean	23	1	52.6	W. limb.	Mean	23	4	1.1	E. limb.
		4	1.1	E. limb.					
		5	53.7						
Reduction of wires	23	2	56.85	mean passage of centre.					

By Dr. Maskelyne's method.—Add together the seconds and tenths, and multiply their sum by ,2 ; add or subtract one-fifth part of a minute, or 12 seconds, as many times as will convert the same into as many seconds as were indicated at the centre wire ; for the fractional part of the second is all that, in a good observation, is wanted to complete the reduction.

Thus, in the above example of the sun—

	s.		s.
1st limb	49	2nd limb	58
	22.5		31
	52		00
	24.5		33
	55		3.5
	203.0 × ,2=40.60		125.5 × ,2=25.1
	Add +12		Sub. −24
Western limb =	23 1 52.60	Eastern limb =	23 4 1.1

which affords the same result as the common method. Now, in the second observation, the first wire was lost, therefore reject the fifth and merely add the three centre together,

h. m. s.
9 37 37
38 47
39 57.5
26 21.5
9 38 47.16 reduction of wires.

Now, the centre wire might have been missed, and the two extremes obtained; in that case we should have used their mean, as in the observation above.

h. m. s.
9 37 37
39 57.5
17 34.5
9 38 47.25

This shews, that the wires are not truly equi-distant, or that the observation was not truly made, but as the result involves a decimal division, by a chronometer beating five to two seconds, and dependent on the signal to the assistant, this cannot be taken for granted.

Much more could be said on this subject, had not the copious extracts from the valuable treatise just quoted, already occupied so much of the present work. It is, unfortunately, too voluminous for the library of the sailor; but it is to be hoped that the time is not far distant when something on a smaller scale, and more immediately adapted to professional men, may be found in every ship.

To determine the apparent time of transit of a Star.

From the R. A. of the star, (increased if necessary by 24 hours,) subtract the R. A. of the sun. The result will be the *approximate* apparent time of passage. To this apply the longitude in time, and compute the Sun's R. A. to the nearest instant. From the R. A. of the star, subtract this reduced R. A. of the sun, and the result will be the apparent time of transit.

Now, as the rate of the watch is to be found on mean time, and the computed passages must depend on such motion, it is preferable to reduce the passages to that standard.

This is more conveniently attained by the present construction of the Nautical Almanac, which affords the sidereal time at mean noon.

Thus: Reduce the sidereal time for mean noon, as given in page II. of the Nautical Almanac, to the meridian of the observatory, (by rule, p. 496, at the end,) viz. by the addition, at the rate of $9^s.8565$ per hour, if west, and minus if east. From the R. A. of the star subtract the reduced sidereal time; the result is the sidereal interval beyond noon. Reduce this time to mean solar, by the application of the tables for acceleration of sidereal on mean time; the result is the mean time of passage.

In determining the transits by this course, the sidereal time is more conveniently referred to, if the rough work is retained, which should be invariably observed. The student cannot do better than make himself fully acquainted with the additional matter in the present Nautical Almanac, by which many of his difficulties will be removed.

In computing the Zenith distances.

If the latitude and declination of the object have the same name take their difference, otherwise, their sum equals the meridian zenith distance.

Such, then, as far as the subject has been traced, are the duties of the observatory, which occupy the mind of the surveyor by night; the day being devoted to the survey.

Another instrument yet remains to be noticed, the operations of which, in its varied forms, call for the most minute and patient attention of the surveyor.

MAGNETIC FORCES.

These are the magnetical experiments. It is to be regretted that no work treats so familiarly as could be wished on this subject. The dipping needle is the chief instrument. This, like other instruments, varies in size; but those generally supplied by government vary from ten to twelve inches in length, and are enclosed in a brass circular case, of a diameter as much exceeding the length of the needle as will admit of its motion, clear of the graduated circle within. The axis of the needle is very slender, and plays on two straight-edged agate supports. The brass circular case is placed erect on its circumference, and attached to a pedestal, which has motion in azimuth, (similar to a theodolite,) the lower circular plate of which, however, is not divided. The axis of the needle is supported by two bars forming the horizontal diameters of the case, and between which the needle swings. The whole instrument being levelled by a small spirit level at the pole of this vertical circle.

To use the instrument, the circle is directed in the *magnetic* meridian, by a compass, or by one of its needles suspended on the point of a pendulum, resting on the bearers of the dipping needle. The dipping needle is then carefully placed on its bearings, and a clog, having a fine notch, is raised to centre it truly, (which should be done at its dip mark, as its motion may otherwise work it out of the central line between the upper and lower divisions.) The needle is then given motion by hand, or by releasing it from its clog, by a catch sometimes adapted at the arc to which it is intended to swing it; or, lastly, by a magnet applied distantly, so as gradually to increase its vibration a little beyond the arc required. Nice observers object to this latter mode. For the dip observation then, slight, or merely free, action is all that is required. When it stops, read off the divisions it indicates, and give fresh disturbance. Continue to read off three, with the face east. Invert the needle on its axis, and when it has nearly stopped, centre the axis afresh by the clog, and take a similar number of observations. Reverse the instrument, and repeat the observations, with face west. The mean of these should be the dip. There may, probably, be three needles. One *only* is to be used for reversing the poles; the others are to be used for the dip, as just described; but not to be allowed to touch each other, or a magnet. These will be presently treated of.

The same *identical* needle is then to have its poles reversed. Take the bar magnets which are furnished with the dipping needles: next provide a board with a hole to admit of the axis, so that its collar may fit fairly, and that the needle may rest flat on it, without bearing at the centre Place the board before you, with the north end of the needle to your right. Take a magnet in each hand thus: in the right, the end of the bar having the mark across, downwards. In the left, the same mark upwards. Bring the bars over the axis, about a foot above it, without approaching each other within two inches:—bring them down vertically on the needle, (as directed with the marks) about an inch on each side of its axis; slide them outwards to its ends with slight pressure; repeat this three, or four, times. [Avoid scraping with the sharp edges; it takes off a coat of metal, and destroys the balance.] This process deprives the needle of its power, and by a continuation of a dozen more rubs, will reverse its poles. That which was before north, being now south. Complete a similar series of observations (to that before directed) with the needle thus changed; the mean of poles direct, and reversed, should afford the true dip. Several such series of observations should always be made and transmitted before quitting England, and on a spot where they can conveniently be resumed on the return of the ship.

Example.

Thus: Face E.	49° 5′		(Poles afterwards inverted) Face E.	46° 5′	
	49. 2			46.10	
	49.23			46.24	
Axis inverted	64.20		Axis inverted	59.58	
	64.30			60.10	
	64.30	Mean 56° 43′		60.18	Mean 53° 13′
Face W.	48.20		Face W.	46.15	
	48.11			45.40	
	48. 7			45.56	
Axis inverted	65.20		Axis inverted	60. 3	
	64.50			61.15	
	64.52			60.10	

	° ′
	56.43
	53.13
	9.56
Mean dip	54 58

This, then, is the dip result. It is next to be tried for intensity, as swung in the plane of the magnetic meridian, over a determined arc. Say 40° on each side of the dip, (or = semi-arc of 40°.) Some needles are very sluggish, and therefore the extent of vibrations will be guided by the arc, but they must be referred to a known position. To make the observation does not *require* an assistant, but the *beginner* will hardly make much progress by himself. Cause the needle to swing from its *centred* position, at an arc exceeding that intended, and watch the vibrations until they coincide with the division intended, then note, " stop," observing, that the counting commences *after* the " stop;" at the 5th vibration note, (calling stop,) 10th, 15th, 20th, at each 5 up to 50; count on to 100, and note the 100th; numbering 5, 10, 15, &c., after the 100, up to 150; continuing to note every 5 until it ceases. The intervals, then, between the hundreds are the vertical vibrations, in seconds. These are to be constantly repeated, and upon the two needles. This will only afford the intensity in the plane of the meridian. The packing-case of the instrument is fitted to suspend these needles horizontally by a fine fibre, and at its base has an ivory graduated circle. Find the magnetic meridian by the suspended needle at rest, and let it remain some hours to run out any torsion there may be in the fibre. (As the case has no connexion with the dipping needle they can be used separately.)

On the ivory circle are two legs, moveable on a centre, and which throw up to stop the needle. They have motion in azimuth, and can be set at any arc. Determine the arc at which you intend all your observations to commence *during the voyage*. Say 30°, and set these arms at 30°. Swing the needle beyond 30°, and pull the catch, which throws these legs up. This holds the needle at that arc. When ready, let go the catch, note the vibrations similarly to the last, bearing in mind, that as the motion at the extremities of the arc is sluggish, and undefined, the note should be, at its passage over the mark of the magnetic meridian, which is a line cut on each glass of the case, and should be brought in one with the suspension fibre, if the instrument be fairly levelled. These observations should be carried on as far as the motion can *truly* be measured, which at 300 ceases to be distinct. The *(diminished)* arc at each 100 is to be noted, and that at which the observation concludes.

These instruments are so extremely sensible of the approach of iron, that they are affected even by the contents of the pocket. Therefore, in placing them, great care should be taken that the spot selected

is not only clear of this metal, but of basaltic or volcanic matter, or even of spars, which have long been lying in the mud in the magnetic meridian, which thus acquire polarity.

Under the head, then, of "Magnetic Observations," the surveyor is called on to produce the following :—

Magnetic observations, as connected with the variation of the compass.

Dip of the needle.

Vertical forces in the plane of the magnetic meridian.

Horizontal forces out of the meridian.

The whole referrible to his first point of starting, where they should be repeated on his return.

The following Problems and Remarks were kindly afforded by the Rev. G. Fisher, late chaplain of his Majesty's ship Victory, and to whom I am indebted for all the instruction I have received on this subject.

Problem I.

Given, the times of a magnetic needle making a certain number of horizontal vibrations at any two places, to determine the relative forces soliciting the horizontal, or compass, needle.

Since the forces are inversely as the squares of the times of making a given number of vibrations, we have the following.

Rule.

From the logarithm of the time of making a given number of vibrations at any place, as London for instance, subtract the logarithm of the time of making the same number at any other place; twice the difference is the logarithm of the horizontal force at this place, the force at London being unity.

Example.

Time of 100 horizontal vibrations at London	$= 268''.6$	.... log.	2.42911
Ditto at Malta	$= 220''.1$	.... log.	2.34262
			0.08649
			2
Horizontal force at Malta	$= 1.489$	.... log.	0.17298

That is, the force soliciting the compass needle at London, is to the same at Malta, as 1 to 1,489.

Problem II.

Given, the relative horizontal forces at London, and at any other place, (as determined by the last problem,) and the dips of the needle, to compute the relative whole forces, *i. e.* the forces in the direction of the dipping needle.

Rule.

Add together the log. cosine of the dip in London; the log secant of the dip, and of the horizontal force at the place of observation; the sum, is the logarithm of the whole force at this place; that at London being unity.

Example.

Let the relative horizontal forces at London and at Malta be as 1 to 1,489, and the dips at each place 69° 40′, and 54° 17′ respectively.

Dip, London	69° 40′	cosine	9.54093
„ Malta	54.17	secant	10.23375
Horizontal force do.......	1.489	log.	0.17289
Whole force at Malta....	0.886	log.	9.94757

That is, the force soliciting the dipping needle in London is to the same at Malta, as 1 to 0.886. The same method of computation will apply to any other places.

Note. By means of the vibrations of horizontal needles, suspended from their centres by fibres of silk, the forces soliciting the compass needle in different parts of the world, may be determined by problem I.; and knowing the dip of the needle at each place, the forces soliciting the dipping needle may be computed by problem II. But, when the dip at either place is considerable, the application of problem II. to experiments made with horizontal needles becomes objectionable, since the unavoidable errors in the determination of the dips, introduce very considerable ones in the results. In this case recourse must be had to the dipping needle; and the times in which the needle, when in its natural dipping position, makes a given number of vibrations at each place, as well as the relative forces, must be determined by the following

Problem III.

Given the times of completing a certain number of vibrations in the direction of the dipping-needle at any two places, to determine the relative forces in that direction.

Rule.

The same as problem I.; substituting the whole force for the horizontal force.

Example.

Time of 100 vibrations by a dipping-needle in London	=	293″.5	log. 2.46761
Do. " in Malta	=	308.1	log. 2.48869
			9.97892
			2
Whole force at Malta		0.907	log. 9.95784

That is, the whole force at London is to the same at Malta as 1 to 0.907; which result is obtained independent of the dips. By experiments with an horizontal needle, it was found to be as 1 to 0.886. When the dips are not considerable, and determined with tolerable accuracy, a *mean* between the results obtained with horizontal and dipping-needles seems preferable, since the superior delicacy in the suspension of horizontal needles is nearly counterbalanced by the errors in the determination of the dips, and those caused by the different adjustment horizontal needles require in different parts of the world.

As these experiments are easily made, and at little expense, it is very desirable that scientific navigators should avail themselves of the opportunities which are frequently afforded them of contributing so essentially to the interests of science; and it is only by experiments of this nature that we can acquire a knowledge of the distribution of terrestrial magnetism. It is almost unnecessary to state, that the magnetism of the needles employed for this purpose should never be interfered with, and that they be kept from rust, and other causes likely to lead to any derangement of this nature; since it is a great object in these experiments, that their magnetism remain constant,

otherwise the results are no longer comparative. The same circumstance suggests the necessity of frequently determining the periods of vibration *at the same place*, particularly before and after the completion of the voyage, in order that errors arising from this cause may be detected.

Since at mean temperatures it has been found that an increase of heat produces a diminution in the magnetism of needles, it is advisable that the observations be made at as near the same temperatures as possible, to render any correction on this account less necessary; and that the thermometer be registered when an observation is made.

The first semi-arc of vibration with horizontal needles, having the usual silk suspension, need seldom exceed about 15° or 20°, and the less the better, provided a sufficient number of vibrations can be obtained. In dipping-needles, the axes of which in general are made to vibrate upon polished edges or strips of agate, the friction is very considerable, which rapidly diminishes the extent of arc, and number of vibrations, and makes it necessary that the first arc of vibration should be considerably greater. In most instruments, if the first semi-arc be about 40°, and the last about 10°, it will be found sufficient. Much, however, depends upon the nature of the instrument, and must be left to the judgment of the observer. It is only necessary to observe further, that the experiments should be made between the same limits of arc.

Our knowledge of the laws by which this distribution of the terrestrial magnetism is governed, is at present exceedingly limited. Whether we should refer the cause to an active agency within the earth, or, what is more probable, to its surface, still remains a matter of uncertainty. Taking either of these causes to be the true one, it has been usual, as a sufficient approximation for the explanation of many of the phenomena of the dipping-needle, to refer the terrestrial magnetism to an hypothetical magnet within the earth, by supposing the magnetism to be concentrated into two magnetic poles very near to each other, and to the earth's centre; which supposition is equivalent to that of an infinite number of small magnets parallel to each other, and distributed equally upon the earth's surface; or, indeed, through any other concentric strata. For general illustration this hypothesis may be perhaps sufficiently explanatory. It is, however, in many cases very incorrect; as it follows, that at all places having the same dip, the magnetic forces are equal; and that the magnetic equator is a great circle of the terrestrial sphere; neither of which is

the case. But although the formulæ deduced from this hypothesis do not appear by experiment to represent correctly the laws by which these phenomena are governed; yet, until a more satisfactory elucidation of them is given, they are not without their use, since by tabulating the results, both of experiment and theory, the observer is frequently enabled, by means of a column of differences, to detect an error or discrepancy in his experiments, which otherwise would have escaped his notice; for this reason they are here given in a shape that it is to be hoped will be intelligible to persons understanding the use of logarithms only.

Problem A.

Given the horizontal force soliciting a magnetic-needle in London, (equal to unity,) to compute the same at any other, the dips at both places being known.

Rule.

1. Find the number corresponding to twice the log. secant of the dip in London (rejecting 10 from the index,) to which add the number 3, and call the sum A.

2. Find the number corresponding to twice the log. secant of the dip at the other place, to which add 3, and call this B.

3. From the log. of A take the log. of B, and half the difference is the logarithm of the force required.

Example.

Suppose the dip in London to be 69° 22′ to compute the horizontal force, at a place where the dip is 20° 5′.

Dip, London 69° 22′	Secant 0.45298	Dip at other place 20° 5′	Secant 0.02724
	2		2
8.053	log. 0.90596	1.134	log. 0.05448
3		3	
A = 11.053	log. 1.04348	B = 4.134	
B = 4.134	log. 0.61637		
	2) 0.42711		
1.635	log. 0.21355		

That is, the horizontal force in London is to the horizontal force at the place where the dip is 20° 5′, as 1 to 1.635.

Problem B.

Given the force in the direction of the dipping-needle in London (= 1) to compute the same at any other place; the dips at both places being known.

Rule.

1. To twice the log. sine of the dip in London add the constant logarithm 0.47712, reject 20 from the index, and take the corresponding number from 4; call the remainder C.

2. To twice the log. sine of the dip at the other place add 0.47712, reject 20 from the index, and take the coresponding number from 4; call the remainder D.

3. From the log. of C take the log. of D, and half the difference is the log. of the force required.

Example.

Suppose the dip in London to be 69° 22′, to compute the force in direction of the dipping-needle at a place where the dip is 19° 15′.

Dip London 69° 22′	Sin.	9.97121
		2
		19.94242
	C. log.	0.47712
2.627	log.	0.41954
4		
C = 1.373	log.	0.13767
D = 3.674	log.	0.56514
	2)	19.57253
0.6113		9.78626

Dip at other place 19° 15′	Sin.	9.51811
		2
		19.03622
	C. log.	0.47712
0.326	log.	—1.51334
4		
D = 3.674		

That is, the whole force in London is to the same where the dip is 19° 15′, as 1 to 0.6113.

We can now compare the experimental results obtained by problem I. with those computed by problem A. In the same way the results obtained by problems II. and III. may be compared with those computed by problem B.

Before quitting the subject of observatory duties, it may be necessary to remark, that although the measurement of bases by chains, rods, or sound, has been introduced, we are not unfrequently compelled to have recourse to those dependent on astronomical observations, either on the meridian or parallel. The latter, or "meridian distances," have been measured with great exactness by rockets, as described by Captain F. W. Owen. Thus, at an intermediate station, say 20 miles from the extremes, let a series of rockets be fired as nearly perpendicular as possible. The observers at the extremes note the exact moment of explosion by chronometer; the difference between the *mean times* at the extremities of the base will afford the meridian distance.

The determination of heights by trigonometrical measurement has also been dwelt on. They may also be obtained by barometer; for the rules, &c. connected with, which we must refer the reader to the works of Galbraith and others.

The following may not be unworthy of the attention of navigators generally. In some vessels chronometers are suspended in cots, and men of great ability have sanctioned it. Yet it has been found, that if the suspension be on one point only, and admit of circular motion, that a most material change in rate results—*as much as double;* and if the chronometer be closely observed, it will be found to have acquired a motion from its escapement, or corresponding to its beats. If a watch be laid on its glass this is immediately apparent.

It is to be feared that we have already ventured beyond the limits of a work of this nature. We have endeavoured to point out the various subjects which the pursuit of this study would embrace, and shall terminate by treating on such points as may, it is to be hoped, be found useful to the traveller, or serve as amusement.

HINTS TO TRAVELLERS.

Having closed our remarks on the subjects immediately connected with the profession and instruments of a superior class, it is proposed to treat on subjects more immediately applicable to travellers who may find themselves in situations where important observations ought to be made, but are not perhaps furnished with the requisite instruments.

At the same time the experiments may furnish amusement to those inclined to follow out all that can be completed without such aids.

Great difficulty attends the transportation of delicate instruments by land, and their bulk also is another inconvenience. An instrument which shall be free from liability to derangement from such motion has long been a desideratum. It occurred to me that such might be partly met by the use of the equilateral triangle, constructed in brass, furnished with telescope and level, and having its adjustments in its legs. One limb to be graduated to inches, and furnished with a vernier, reading to the thousandth part of the inch, which, with its constant radius, could afford the means of readily computing the angles. Such an instrument would perform the duties of level, theodolite, altitude instrument, protract angles, and even be used as a beam compass. It is now constructing by Mr. Cary in the Strand, and it is proposed to include within its case (which will be about 12 inches by 3, internal measurement) all the small instruments the traveller can fairly look for.

It is impossible to furnish a complete description of an instrument in progress; as, the object being simplicity and portability, many of the minuter fittings have already been superseded, in order to free its adjustments from any thing which may perplex those unaccustomed to astronomical instruments.

The telescope centres in each angle; therefore, when centred on the base, and the riding level attached, it becomes a level, which is proved by its motion in azimuth. By inserting the pins through the sockets, at the angles, it can be used to lay off angles or distances

under eight inches. If above eight, another limb must be used, and if above sixteen, the whole length may be rendered available, viz. twenty-four inches.

Our purpose, however, is to endeavour to point out the simplest methods of overcoming difficulties, should instruments be wanting, and to show that much can be achieved even by a line and rule.

Amongst savages, the sight of metal may induce them to commit murder for the sake of plunder. In foreign countries, the traveller who displays his instruments may excite suspicion, be annoyed in his attempts, or even ordered to quit the territory. In the case of hostility, many schemes may be pursued, which may not only serve as a diversion, but the enemy may even be made to render effectual aid.

This, however, is not to deter the traveller from proceeding fully equipped: when his instruments fail, or are gone, then he may fall back on his *schemes*, which, however, he ought to *practise* beforehand.

The short list of requisites may be included in the following:—A good watch, with second hand, and beating five to two seconds; a pocket-case of folding compasses; an ivory scale, containing on one side the protractor and usual scales, and on the other side the English inch, divided into thirty parts on the first division; and beneath, the corresponding graduation of the measures of the various countries. They can easily be combined within ten lines. This will afford him the means of instantly reducing foreign measurements into British.

His pocket-compass may combine the circular thermometer on its face, and a clinometer on its reverse. A measuring tape and pocket-rule, also a strong ribbon six feet long, which he may readily graduate himself by indelible marking-ink, (after it has been wet, dried, and ironed.) If he can afford a silk braid of 50 or 100 feet, marked at every 10, he will find it important.

The flexible tube may possibly find space. It will be found of value in determining levels; but its most important use is in obtaining a wholesome draught, when not otherwise to be procured. It may save him bucket and rope at the well, will save the danger or inconvenience when drinking from a torrent, and will at all times enable him to take his draught in a convenient position; and draw through palings, rushes, or other impediments, supplies which could only be obtained at the verge, (if at all,) in a turbid unwholesome state.

Failing, then, this catalogue, he proceeds to meet his difficulties with such means as he may reasonably expect to find.

Geometry is part of our school education; but what were we taught, and how was it applied to impress its principles on our minds? Sufficient was learned by rote, a few figures projected with the compasses, (considered as playthings,) and then it ceased. Little interest is excited in after life, although frequent opportunities offer for the exercise of this study.

Had practical geometry been made the pastime of the schools, then every field, which in younger days elicited the ingenuity of the scholar, would bring to his mind the foundation, the elements of the *practical* course he had gone through, and induce him to think how he could have achieved this or that manœuvre in a neater or more masterly manner, for, with those who are intent on the study, every action partakes of the method and rule of this science.

It may possibly be shown that a considerable portion of ground may be trigonometrically surveyed, and computed, and space of water sounded, and laid down by the same laws, without one astronomical instrument being used, one angle measured, or the water interfered with by boat. The practice of such operations, when leisure admits, and, which is more important, the theory constantly worked out in the mind, enables the traveller, not only to perform his manœuvres instantly and masterly, but to tinge every other operation in which he engages, with a decision, an accuracy, and rapidity of achievement which give confidence to those associated with him, and character to his productions.

Various have been the amusing propositions offered by authors who have treated on mathematical subjects; and it would have formed a valuable little volume, if those which were circulated amongst the engineers or cadets at Woolwich, (by the various men of talent who have gone through that establishment,) could have been arranged. Such, in particular, as related to rapid conclusions of heights and distances, &c., as calculated to perform expertly the operation of a dangerous reconnoitre. Yet such can be attained by practice and thought; by proposing certain objects, and solving them by the direct and simple principles of geometry.

Boys are accustomed to measure heights and distances long before they have any idea of the laws which govern the results, and, but too probably, never attain that knowledge. The stick, of a certain length, is held at arm's length; the party recedes from the object until the stick becomes the chord of the arc, of which the distance from the eye to the extremities is the radius. He paces the distance, and

exultingly exclaims, "It is so much." No solution is attempted. He is "a clever boy," is caressed, and there ends his knowledge, which on that point is considered sufficient. In after life, he would rejoice to be able to investigate, and apply the truths of science when opportunity has offered distinction, and possibly his less brilliant schoolfellow has taken precedence.

Before proceeding to investigate any such questions, it is material that the knowledge of our own scale be perfect. The student in such affairs should first bring himself to the standard, and should insert in a book kept for the purpose, every minute circumstance. His height without his shoes, and hair smoothed; length from heel to hip; heel to eye, (measured by bringing a window down to his eyes.) The number of paces he takes in 100 yards moderate time (three miles per hour). How few he can *conveniently* achieve it in, at the same rate. Let him repeat this frequently, noting the intervals by watch. Try the same with weights (of shot) in each hand; and also at quick pace; at pressed time, but measured. The number of paces he averages in the mile. By a course of such experiments, and contrasting his own body, habits, constitution, &c., with those about him, he is enabled to form correct conclusions, not only in the operations of which it is proposed to treat, as connected with himself; but in estimating fairly the force he may have at command, and how far each man does his duty. No man can confidently go to his work, or at least with *discretion*, until he knows the powers he has at command. If risk be at any time incurred, he then knows what ought to be done. He should first commence with pacing. It of course varies, but from experiment, the mean has been found nearly as follows:—

Pacing = 30 inches per pace of 108 in a minute = 270 feet, which equal 16,200 feet in one hour, which equal 3.068 English miles, or 2,66 geographic.

Quick = 30 inches, at 120 per minute = 300 feet = 18,000 per hour = 3,41 English, 2,96 geographic.

Slow = 36 inches, may average 60 per minute = 180 feet = 10,800 per hour = 2,04 English, 1,75 geographic.

The step of track horses, on moderate speed, at the sides of a canal, may be assumed at three miles.

A fair walking horse at five miles in the hour.

Of the various methods of estimating, or measuring, distances, those will be selected which can fairly bear investigation.

To return then to the stick. With instruments for measuring

angles, it can readily be determined at what distances certain objects will subtend certain angles; and by military men it is frequently the practice from the average of a number of men subtending a division on the pencil-case, to estimate their distance. Now, to reduce this species of measurement within the bounds of mathematical precision, will occupy our attention.

First, then; determine the true distance between the eye and the stick to be grasped, the thumb being laid longitudinally along it, and the socket-joint being its abutting rest. Suppose, then, that a stick 30 inches in length is to be made use of, its graduations being clearly visible at that distance from the eye. Now, the mean distance at which the arm will steadily carry the stick, has been estimated at 26 inches, and the convenient length of stick the same. Provide a strong silken line, with a pearl button at its centre, and loops, or marks, at the ends, and a centre line, which when tied below the centre of the stick, and the button kept between the teeth, will admit of its being projected 26 inches from the eye, the centre mark being nearly on its level. Secure the other two ends 13 inches above and below the centre, so that the centre line may nearly preserve the perpendicular to the stick.

Now, it must be evident, that if an object be viewed equally above and below the centre mark, the angle is readily computed from the chord, or the half chord and perpendicular. Our object, however, is to obtain a gauge, which will obviate calculation, and render *pacing* the only point to be gained. (We must, therefore, to illustrate our proposition, go to paper for proof if required.)

Select an object which stands on level ground, and establish marks at 10, 20, and 30 feet perpendicularly, and let similar distances be measured horizontally in a direct line from it, noting the height of the eye as a mark.

Standing at these several distances, the eye and toe being nearly vertical, note the divisions on the stick which subtend these distances.

Try this repeatedly, and carefully, and note the results. The mean will afford a standard to be made use of in all such measurements.

By construction. Draw a base A B, and at its right extremity erect a perpendicular equal to 20 feet. At 20 feet laid off on the base to the left, erect a perpendicular, and lay off 5 feet 6 inches as the height of the observer's eye. From that point draw lines to the ex-

tremities of the opposite perpendicular. Now, projecting a middle line of 26 inches, and a base at right angles to it, corresponding to the arm and stick; the stick, or chord of that arc, will be found to be 26 inches, and the radius about 29; if, therefore, the span be 29 inches from each side of the button, the height of an object can be rapidly approximated, by viewing it at the marks on the 26 inch length, and pacing the distance to the base. The value of the angles throughout the whole length may be readily computed, and by increasing the distances above and below the centre mark of the stick, an equilateral triangle may be formed, to meet other purposes, as will presently be shown.

Thus: Let it be supposed that the object is inaccessible. Here, then, we are unable to walk up to it. (Had the schoolboy been questioned on his geometrical knowledge, possibly he would have been puzzled.) However, form the equilateral just proposed, and turning the stick horizontal, view the object over one end, and fix on another in the line of the opposite; if an assistant is at hand, let him fix a stake within 10 or 15 feet of you in that direction. Leave a stake where your *toe* was. Keeping the two stakes in line, walk in that direction until the stake left, and the object, are viewed on the sides of the equilateral, and the former gauge for altitude is brought to agree with the object. The distance between the positions is the height, and is capable of mathematical solution. Thus, the chord gives the angle of elevation at both stations. The figure being an equilateral triangle, the distance at which the object was viewed under similar conditions, will readily afford its height, as the bases to the object must equal that measured.

Another problem, showing the value of the equilateral, is very simple. Wishing to determine the width of a piece of water, two trees on the edges were selected, and receding, I estimated, on bisecting perpendicularly, the line between them, bringing them respectively over the limits of the stick adapted to the *equilateral gauge*. On pacing the distances to each, I found that one gave 34,5, and the other 33,5, consequently I assumed the distance to be the mean $= 34$; and as my paces were estimated at 30 inches, $30 \times 34 = 1020 = 85$ feet.

In De Malortie's Treatise on Topography, he mentions "That the peasant approximates his distance, by observing the object to which the distance is required, in line with the corner of his hat, and, *turning on his heel*, brings some accessible object into the same range."

This is objectionable; yet as all chances of error should be avoided, another version, with but slight variation, will be substituted, which has not unfrequently been used for levelling.

Pass a handkerchief round the neck, bringing the ends down in front, which attach to the end of the stick. Let the end rest against the solid part of the hip. Grasp the stick firmly at the end, and keeping the arm extended, slide the hand gradually down until the object is just visible in line with the thumb. Now, it must be evident to a seaman, that this is a *derrick*, and that its motion over 90 degrees, or more, must be very nearly equal, and corresponding to the fair motion of the head, without shifting body *or feet.* If, then, an inaccessible object be viewed by this method, and the same angle of depression transferred to some other, accessible, the distance to it may be paced, and fairly estimated. This problem may frequently be solved on objects within 100 yards, and a little practice will teach that, on *actual measurement*, the correctness may approach within one foot in that distance.

The traveller, then, wishing to put in practice any of these problems, has merely to cut a stick, and knowing his gauge, (by rule, hat-band, diameter of hat at crown, &c.) determine his distance. On his return to his abode he should note his results, and measure the stick carefully.

The following, which are connected with instrumental measurement, may, nevertheless, be applicable to the stick on which the second column may be computed and marked. It is taken from a work on Land Surveying, 1829. (Anon.)

	° ″	° ″	
1 multiplier.	45. 0 ang.	Ang. 45. 0	1 divisor.
2	63.26	26.34	2
3	71.34	18.26	3
4	75.58	14. 2	4
5	78.41	11.1	5
6	80.32	9.28	6
8	82.52	7. 8	
10	84.17	5.43	10

The chords to the arcs under 45 are easily computed, or projected on paper.

Rule. Make a mark on the wall equal to the height of the eye, and recede until the stick subtend the mark or required degrees; or by reflecting instruments;—until the angle set on the instrument coincides with

the objects. Measure the distance to the wall, and multiply or divide as the table specifies, the result will be the height above the eye mark, to which add its height for the whole measurement.

Ex. Thus: Angle, $63^{0}\ 26'$; multiplier, $2 \times$ base $= 28$ feet 10 in.$=$ 57,8; eye, $+ 4.11 = 62.7$ feet.

We will not yet forsake the stick; but we must now procure one fully our own height.

Let it then be required to level and examine the course of a river, in a country where the sight of metal is the sure prelude to robbery, at all events suspicion, and that every motion is closely watched. This, then, can only be effected by endeavouring to convert it into some game or sport. The height of the eye being known, the *toe* above the heel, and the length from eye to hand 26 inches, compute the hypothenuse, which would produce the hand at right angles. Or, avoiding all niceties, in such a case as that proposed; grasp the stick about a foot above the eye, fix on an object the height of the eye, and recede from it, (on the water-line, if possible.) Extending the arm fairly, slip the hand down, until the mark be just clear of the thumb. This is the level gauge. Mark it with a piece of twine. By observing any object at this gauge, the distance may be paced, and it will be on the same level as the eye was at the first position. Such an operation, without an assistant, would be tedious. Some game or sport must be devised. If a bow and arrows are available, the one may try to hit his object, and induce the whole party to pace the distance, the assistant marking a stone or bit of wood, bark, &c., with the required record, which may be considered a mark of reward, or reproof for failure. Weights or stones may be cast. [Trivial as these points appear, there are those who have suffered from inattention, and I may safely say I owe a speedy relief, when in danger, from making my adversaries *amuse themselves* by hoisting the ensign union downwards, and the recovery of the ensign previously, by playing on their credulity.]

Had some of our travellers originated amusing plans to blind the natives, many more valuable materials would have been afforded.

To determine the distance across a River by measurement of bases. Plate IX. fig. 3.

Required the distance from A to x.

Having a line of 50 fathoms, (or 300 feet,) a distance of 300 feet was measured from A to B, keeping A x truly in line. Keeping one

end fixed at A, the other was carried to C, and the ground scored where it was judged it would form an equilateral triangle. Shifting the end from A to B, the equilateral A B C was completed, which was then very carefully remeasured. The line was then continued to D, making B C D = 600 feet, and was truly in line by the stakes B C, being exactly in one viewed from D. Standing behind D, at *b*, the assistant placed stakes at *a*, *a*, *a*, *á*. The base A D was then accurately measured. Now, it is evident the sides of the triangle A C D are known, and therefore the contained angle's result. All we require then is another known angle to cut the object, that at A being $= 90^{\circ}$. This is effected by causing the assistant to move one of the stakes *a*, until viewed from C it is truly in line with *x*, as at E. Measure A E, and compute the angles E and C from the legs and included angle, (or three measured sides.) It is evident that the angle to the object *x*, at E, must be equal to $180^{\circ} - E$; therefore, the distance can be determined on the base A E. Now, it is also evident that a further verification may be obtained by taking the distance *e é*, in line with *a á*, and computing the angles. Any triangle constructed on the line *x* A B would have answered, but the equilateral has been preferred for its simplicity, all the internal and external angles resulting clearly.

This question might have been readily solved by the equilateral gauge, had there been distance above and below the object to carry on the measurement. A very simple and convenient equilateral triangle may be constructed on the ground, by cutting three sticks of equal length and "halving" their ends together; taking care that their convex surfaces be inwards, that no obstruction may offer to the side sight. Then, viewing the object on one of its sides, and selecting a mark in line with another ($= 60^{\circ}$ from the object) the base may be measured in the latter line: by fixing a stake where the toe is, and another ten feet in advance in the required direction. Keeping the two stakes in line, recede until the object and stakes subtend 60°, or are seen on the sides of the equilateral. The distance between the two stations will be equal to that from A to *x*.

The system by similar triangles would have answered, but the perpendicular is not so easily gained. It would involve the first, A D, and a second, on A D as C E *a*. If proof of this nature be required, it can readily be met; produce the line A C (as dotted) to C′ = 600 feet; and from that distance complete the line to D, which would then complete a right-angled triangle by the intersection from *x*; at *a*

measure D a. Then D to new mark $C' = 300$, forming the new equilateral C D C′. Then, as D a : D C : : a A to A x.

Now, let us suppose, as in the diagram, plate IX. fig. 3, that it became an object to ascertain if the river was fordable, or to determine its depth; (the distance across being estimated at 100 yards;) that no impediment offered, and that time was available for the complete projection on paper. If a kite was at hand, and the wind favoured, it is evident that the tail might be used to sound; or, a more scientific and complete method would be to affix a curtain ring to the kite line, veer it well up, and by using a bullet and marked twine pulley fashion, through the ring, any parts might be accurately sounded. Here, then, are two ideas; but we have not a kite. It is needless to say, no twine. Obtain twine, and attach a stone with a float at the estimated depth; try this until an approximate depth is found, the stone in question not being sufficiently heavy to immerse the wood. Having gained the approximate depth, cast the stone in above the stream in deeper water, and cause the assistant to watch it, keeping A in line with it; the principal running below, and pursuing the same with a. The instant it sounds, which would be shown by the canting of the float, each would place a mark and measure from two nearest points, by which the depths might be accurately inserted. If the kite had been used, the soundings would have been taken on objects in line, as A x; C, a; c, a, &c.; and the intersecting line measured on the side C D, keeping C B in line. In the event of an enemy being within musket shot of the middle of the stream, and the banks tolerably protected, the kite, although the plaything of boys, is not to be disregarded; it has frequently been used for equally important purposes, particularly in communicating with the shore in cases of shipwreck, and where ammunition or small supplies of food are required to be transported, over bars impassable to boats, is a most convenient aid. A very simple mode of conveying powder through the heaviest surf is to roll it up in *dough*, and grease the outside.

Should it be deemed advisable to obtain a round of angles at any particular spot where battens of three feet long may be obtained, or a deal table; it may be accomplished thus: Construct the equilateral triangle, and stick strong pins through *at the angles*, measuring three feet exact from pin to pin; then bring two pins in line to the object *from which* the angle is to be measured, stick another in the direction of the near pin, and the object measured to, and note the length on

that base to the pin in line with your first object, or zero. Note this as follows:—"by equilateral of three feet on sides, right base, in line to zero (say palm) distance left to Black Rock, fourteen inches;" shift the moveable pin to the line with second object, &c. Now, the angles can be readily computed, as the included angle = 60 and two legs, 36 and 14 inches are given. This will answer for angles as far as 60°. Beyond that, without moving the triangle, bring the left hand pin in line to the object, and place the moveable pin in the *near limb*, the pins and object in line; now the angle will be found by the same rule, and added to 60, will be that required, the angle formed at the distant pin being equal to the external required angle. By this means a complete round of angles may be obtained. Draw an equilateral on paper with the base from, and one apex towards you; call the base A left, B right, and C the near angle. Then, C B call zero, and direct it to the primary object. Keeping the eye at C, cause the pin to intersect any object between B and A. If the object be to the left of A, or beyond 60°, bring the pin at A in line to it, and carrying the eye along the side, C B, fix the pin so that the two may intersect it. Large angles may thus be measured on the ground, and the data once registered, are readily solved at any future period.

Altitudes may be measured to some degree of precision by using a plank of 10 feet, having on its upper edge battens nailed to the sides, so as to form a trough. At each end insert a piece of glass, and make the whole water tight, by putty or dough. Direct the plank to the object, and suspend a plumb-line with heavy weight, so that it may just touch at the 10 feet distance; attach a measured batten, so that it may nearly touch it. Put water, treacle, or coal-tar, into the trough, and bringing the eye to the glass, note the division which intersects the object, and that of the level formed by the fluid. A 10 feet base, and the measured perpendicular, are thus available to obtain our object.*

It not unfrequently happens that a wall may be available nearly in the meridian. At 12 feet 6 above the ground, drive in a smooth round spindle, about the size of a sail-needle, at 6 inches beneath, one similar. Attach a plumb-line (of wire if possible) to the

* If a pocket telescope, with a screw ferrule and socket, be fixed to the plank with a *constant* height to its centre, and one wire to the diaphragm; the altitudes of heavenly bodies may be observed, using smoked glass when the sun is the object. The perpendicular will then be minus the height of the fluid above the telescope.

upper, and at 10 feet radius from the lower, strike an arc on the wall from side to side. On each side, at the same distance from the wall, suspend finer plumb-lines, and placing their loops on the threads of screws, cause *the three to coincide. This is conveniently done by* lights at night. It is evident, then, we have a vertical upon which an astronomer might work until he obtained his *true* meridian. But this is beyond our object. If we observe nightly the transits of known stars which may pass at convenient moments, a rate for the watch may be obtained by subtracting the sidereal acceleration= $3^{m \cdot}\ 55^{s} \cdot 91$ from the intervals.—Vide p. 235.

The arc described on the wall may readily be graduated by computing the distances on a 10 feet radius, or the altitude may be obtained, by passing a rule over the arc so as to cause it and the lower pin to be in line with the star at its transit. The distance from the perpendicular, as given by centre plumb-line, will give the chord of the arc corresponding to the altitude observed.

A similar construction on a wall at right angles would afford the time, and serve to bring that towards the meridian into adjustment.

These are subjects which should occupy the attention of those who intend to travel, even if they are fully provided with instruments. Accident may throw them on their own resources, and they will find that these points, trivial as they appear to be, are capable of close investigation.

When it is considered that 1^{o} on a 10 feet radius would occupy 2,1 inches, the errors, if moderate care be observed, cannot be large.

Such operations may be carried on in a room, simply adhering to the principles of trigonometrical measurement. It will appear hereafter, that if the watch can be rated, or apparent time obtained, or even approximated, by these, or instrumental, means, many important observations may be conducted.

The heights of objects may be very fairly determined by observing the angle of reflexion. Thus, place a vessel containing mercury, coal-tar, treacle, water, or oil, and construct a temporary tripod, to which a plumb-line, capable of suspending a weight of 20 lbs. should be attached. (Vide fig. 6, plate IX.) Slit a piece of wood to traverse on this line, and let the centre of the reflecting medium have a piece of hair or silk across it. Observe the reflected image of the object, and cause the piece of slit wood to coincide with it, and the hair or transverse mark. Bring the body erect, so that the value of the

height of the eye may be accurate, and the toe plumbing the eye recede until the reflected object and stick are in one, (as at plate IX.)

It is evident that three similar triangles are formed. First, the height of the eye equals the perpendicular, and the distance from the toe to reflecting medium, the base. The height to the slit stick becomes a second perpendicular, and the distance from plumb-line to the reflector, a second base. The third similar triangle is that sought, for which the base must be measured.

This is an illustration of the law that "similar triangles are in proportion to each other;" as well as that of optics, "that the angle of incidence is equal to that of reflexion."

Example.

Plate IX. fig. 5 and 6. Wishing to determine the height of the wall A B, a vessel of mercury was placed at D, and the tripod constructed over C. The mark at E was then found by sliding the forked stick on the plumb-line. Receding, the mark at E and the reflected object (A) were made to coincide. The measurements were then found to be as follows: height of eye, 5 feet 6 in.; toe to mercury, 11 feet 8 in.; mercury to B, 36 feet 6 in.

Height on plumb-line, 3 feet 6 in.; dist. C D, 7 feet 9 in.; base B D, 36 feet 6 in. It was then measured, as in fig. 6, by lying on the ground.

Length from eye to heel, 5 feet 6 in.; height of plumb, 3 feet 8 in.; B D, 25 feet 6 in.; required the height by each measurement.

As the triangles are similar, we have 1st. As the base of the minor triangle =11,66* : is to the height of eye 5,5 : : so is the base of the greater triangle B D = 36,5 : to its perpendicular A B = ... 17,22

2nd. As C D 7,75 : C E 3,5 : : B D 36,5 : A B 16,48

3rd. C D (fig. 6) 5,5 : E C 3,66 : : B C 25,5 : A B 16.97

(Measured = 16.83.) Mean height.. 16,89

A third method having been introduced in the above example, it is therefore proper to explain it.

The body, or customary height allowed for the eye, may be rendered available for such measurements. Thus, in fig. 6, with a similar tripod, find its perpendicular mark on the ground, and there place a peg.

* Decimally.

Cause a fine plumb-line to traverse over the horns of the tripod. Placing the heel gently against the peg, and extending the body so that the line may intersect the object, cautiously raise the plumb until its lower edge coincides with the most elevated point of the object. The results are; height of eye as base; distance from under-side of plumb, as perpendicular; and distance from peg to object + height of eye, as base of greater angle.

Similar to this is the determination of any height from the length of its shadow; that of a pole, or other known object, being found.

Rule.—As the length of the shadow of the known object, is to the height of the same, so is the shadow of the unknown, to its perpendicular height.

The principal objects of the traveller are, the determination of his latitude, longitude, variation of needle, bearings, heights, and distances. It is to be supposed that he has made himself acquainted with the common methods of determining these points by instruments, or that he pursues a method of registry which may enable others to derive the utmost value from his data. Should he be fortunate enough to obtain his correct time daily, and his watch perform moderately well, it may be in his power to make valuable observations by it alone. It may be important to ascertain the altitude or bearing of a mountain, or fortress, which could not possibly be attempted by direct means with instruments, even if at hand. The secrets of astronomy may, however, be brought in aid, even by an unpractised hand.

It is well known that apparent time will always afford the altitude and azimuth (or true bearing) of a heavenly body to the greatest nicety. To determine the error on apparent time, even by instruments, will scarcely excite suspicion, and may be performed within a chamber. Nor is it probable that observations on the heavenly bodies after dark will meet with opposition. Select a station as near the sea-level as possible, and watch the occultation (or disappearance of a star, behind the object;) in other words, note the time by watch when the star disappears (moving to a position where it will fall on the object required.) The time and latitude will afford the altitude and bearing of that star from the position, consequently the true bearing and altitude of the object.

If a convenient distance for a base can be gained, and another star similarly used, the height and distance of the same object may be accurately ascertained, provided the positions from whence the observations were made, be fixed in latitude and longitude.

BY INSTRUMENTS.

To determine the height of an inaccessible object, by a base measured in a line receding from the position nearest to the object, the angles of elevation being taken at the extremities of the base.

Example.—Wishing to know the height of a hill, from which I supposed myself to be about 500 yards distant, I measured a base directly from it, by placing a stick at the near end, and keeping it in line with the mark on its summit. The base measured was 600 yards. The near elevation was 60°; the distant 30°; eye 4 feet 6 in.; required the height.

Rule.—To the sines of the angles of elevation add the log. cosec. of their difference, and the log. of the base measured; the sum, rejecting tens in the index = the height.

Thus:	Near elevation ..	60° 00′		Sin.	9.937531
	Dist.	30.00		Sin.	9.698970
	Diff.	30.00		Cosec.	0.301030
	Dist.	1800	feet		3.255272
		1558.84	....		3.192803
	Eye	4.5			
		1563.34 = height of object.			

Circuitously this would have stood thus: the outer triangle would first have been computed on the base, and known angles. Thus, the 1st elevation would give the supplement 120° for the obtuse; and the 2nd = 30°; therefore, the angle at the summit would = 30°. Then, as 30° : base : : 30° dist. elev. : to the distance from the base to summit at nearest position. The other triangle, then, being right-angled, with the hypothenuse, and all the angles known, (as 60° + 90° + 30° = 180°,) the perpendicular is readily found.

The same problem applies to measurement from a known height, as supposing the observer on a hill, 1563.34 ft. above the level, the depressions of two objects had been as follows: distant, 30°; near, 60°. By constructing the figure it will be apparent. Then, by right-angled trigonometry, we have two right-angled triangles, of which the height in the above case = 1563.34 is the common base.

Then, as rad. : to height : : tangent of comp. of depression : horizontal distance: the difference between the quantities affords the distance asunder.

By this means, from any known height, the distances and direction

of objects, as shoals, buoys, &c. may be roughly laid down on the chart, and search made for them. It frequently happens that a shoal is thus discovered from a height, when the sun is bright, and the water clear, and although this method is not sufficiently true to fix it, yet it affords the means of *finding* and *correcting* the position.

Allusion has been made to surveying without instruments for measuring angles, or solely by measurement. An example will therefore be introduced, showing that a great space may be accurately surveyed, and the triangulation computed, as well as soundings inserted.

The figure has been projected by the data afforded, and therefore it will afford the student an opportunity of laying down the work of others without a sketch, and tend to elicit his ingenuity and taste. To perform this manœuvre neatly, a telescope, and the suspended flags, as in plate IX., should be made use of.

Example.—On a spot of ground which was required to be surveyed, a house afforded the means of a fair base, its front being due east and west, figure truly square, and sides 50 feet.

On the lower side of the paper, project the house, being a square 50 feet on its sides: call A B its east and west front, and *a*, *b*, its corresponding back. Then A *a* and B *b* are its east and west *meridians.* An equilateral triangle was projected on the front, to the northward, of which C formed the apex. Two lines, of 50 feet each, were extended in line with the front, viz. to D west, and E east. These formed the two right-angled triangles, D A *a*, west; E B *b* east.

Then, on the principle; that at any position where the lines drawn through *two* determined stations cause an intersection, all the angles and one base in that triangle will be given. To facilitate the operation, by multiplying such lines of direction, the first extension of marks took place *north* of A and B, until C D and C E respectively were in line; as F north of A, and G north of B. Extend the line D F north-east, until the objects, G, B, *b*, are truly in line, and call that station H. Extend D, *a*, north-west, until intersected by the line from F G; and mark the intersection I. Similarly, produce *b* E, north-east, and on the same line of intersection carried easterly, viz. I F G; mark K. Extend *a b*, east and west, until the line H F D intersects it, which mark C, and the line G E to the eastward = *d*. Continue these east and west lines, and where the line G C D cuts it west, mark *e*; and F C E, east, = *f*, (all the small letters are on this line, *e*, *c*, *a*, west, and *b*, *d*, *f*, east.) Extend north-east *c* D F H, until it is intersected by *f* K, which mark M; and also

d E G north-west, until intersected by *e* I; which mark L. Now, it was found that L and M occupied positions on the margin of an arm of the sea, which ran towards the house. That the line H M also nearly bounded the eastern side of it, and that the south-west bend was cut by the tangent B C L. The principal outlines of this inlet must now be projected. Keeping *a* A F in line, a stick was placed (No. 1,) at its margin, which was found to be intersected by B C, within 3 feet* of the margin. Keeping C B in line, No. 2 was placed, intersected by *f* G, dist. measured to margin *in line f* G, 7 feet, 2 in. No. 3 fell on the water-line, G E D in line, and No. 2 and D. At No. 4 a difficulty arose; no objects in line were available. The assistant went to the house-front, and placing himself at A, moved gradually eastward, until he caused F to cut it, *at* 5 *feet east of* A. Therefore, laying off 5 feet, a line drawn from thence through F, intersects No. 4. He then went on the line M K F, and found that where the objects A B E were in line, that the position would be cut by H; he therefore marked that position for a new triangle, *g*. No. 5 fell on the line *f* H, intersected by F, 3. No. 6 on the line B, 3, but at a loss for an intersection. Went to westward of L, and caused the assistant to place the mark when he was on the line L M, the distance beyond 6, on the same line to margin, was 2 feet 6 inches. This completed the western margin, L being at the bend, from whence the line ran straight on the direction B C L.

As the line F H M nearly bounded the eastern arm, that line was adhered to as an *off-set* base. No. 7 was placed on line M H, F D, intersected by G E *d*, and L, 3, distance on line G E to water, 5 feet. First off-set, H and *f* in line, 3 feet from H to margin. No. 8, assistant went on line *b d*, with directions to bring E on with mark:—intersected by a line from 15 feet *east of E and M;* distance on that line from off-set base, 5 feet. No. 9 similarly fixed at 10 feet *east* of same spot, distance to margin on that line, 11 feet. No. 10 ditto ditto, 5 feet *east* of mark, (M E in line,) 12 feet to margin, on that line; and, lastly, M to margin, in line to L, 5 feet.

Any further extension of the plan must rest with the ingenuity of the student. He must by this time be aware of the principles, and that every triangle he has projected can be subjected to computation; but he must commence from his equilateral and right-angled triangles, those being his only known bases.

The next object is to sound this arm of the sea. The system by

* Noted to be laid off from No. 1, to margin *northerly*.

kite may be practised; or, as the whole distance across does not much exceed 200 feet, it is possible a high tree may be available. At M such a tree was found. To its summit a line was attached and carried across the arm, the sounding line being attached at 100 feet from the tree, which exactly plumbed M when the line bore a strain. At the numbers on the west side, the line was brought taut, and the depth measured; the sounding line having a white rag, to render it distinct to the assistant. All the soundings, then, were on the radii from M, to the numbers on the western bank. The assistant keeping G and the rag in line, and keeping to the base B E, noted the depths as follows:—First, ($1\frac{1}{2}$,) 18 feet *east* of B; second, ($2\frac{1}{2}$,) 19.6 east of B; third, (3,) $21\frac{1}{2}$ ditto; fourth, (2,) 23 ditto ditto; fifth, ($2\frac{1}{2}$,) $21\frac{1}{2}$ ditto ditto; sixth, (3,) 15 feet east of B, (and E H in line.) This is sufficient to shew the principle; lines drawn from those distances on the base B E, until they intersect the radii, will mark each sounding. By shortening the distance each time, the whole space may be readily sounded and placed on paper. Had this been performed by kite, the principal would have guided his soundings by objects in line, and the assistant would, as before, have worked on one side of a triangle.

Let it be required to run a course of levels from the house to the water.

Procure a mason's or carpenter's level. If not to be had, construct one as follows:—Using a straight-edged plank as a base, construct a triangle. About two inches less asunder than the length of this plank, drive into the ground two stakes, so that they will not be above six inches above the surface. From the apex of the triangle suspend a plummet, and place the triangle on the stakes. Note where the plummet line cuts. Reverse it on the stakes. A difference will probably be found. Make a mark at half the difference, and drive in the stake which appears higher, or that which causes the *apparent* deviation from the perpendicular, until the line cuts this centre mark. Reverse it again. If true, it is ready for use, if a difference still exists, repeat the process until it bear reversing on the same mark. By driving stakes on this principle, the *lower or advance* one only being driven, the levels may be pursued, the distances being the length of plank, and the differences of level the height of the advanced stake, the upper end resting on a stone planted beside the stake, and beaten flat to the ground.

An engine hose, or flexible tube, may also be made use of for this

purpose; comment is needless, it must be evident that when *full* the ends extended to any moderate distance must shew the level.

Geometrical propositions afford full scope for instructive games, and even the principles of surveying may be made subservient to this purpose. Let the object of the game be the reaching some particular point by advancing triangles, the limit of the advanced position never to exceed 60°, or be less than 50°. Each party investigating the manœuvres of their opponent, and a faulty triangle being the loss of a move. Coloured stakes may be given to each party, and equally divided; and should it be evident that long legs led from the *same colour*, cut by one move; although far short in minor triangles, such to be taken as the master-piece. This would originate a habit of measuring angles by eye, reflecting on geometrical questions, and prove of great assistance to the draughtsman. Youngsters, when detained on shore waiting for their officers, and where there is little chance of their boats' crews straying, may do well to follow up such miniature surveys by the lead line, boats' spars, oars, &c.

Next in importance to such pursuits, are those connected with the support of life, methods of procuring, discriminating, and cooking food. Such subjects are equally important to the officer, traveller, or merchant seaman. Accident may suddenly place them upon their own resources, when some little knowledge of the natural productions of land or sea, which may be rendered available for their support, may materially soften their distress.

The customs of savage nations offer many useful examples; and it may not be unworthy of serious consideration, that ability on our part to instruct those amongst whom fate may cast us, even in their ordinary pursuits, generally ensures respect and consideration.

As examples in cooking, the Esquimaux, when he broils his fish, passes a stick through from head to tail, threads it, and sticking the large end in the earth, allows it to project obliquely over the fire, yet clear of the smoke. If he requires it boiled, he half fills a wooden vessel with water, and casting hot stones into it, places the fish over all. This is repeated until boiled. If no vessel to put the water into be at hand, a hollow in the rock may be available, or even a puddle in clay. The same practice holds amongst the Indians throughout great part of America.

Amongst the South Sea Islanders a fire is made in a paved hollow, and piles of stones added to the fuel. The object to be cooked is bound

up in leaves, which should contain much moisture, (as plantain or taro,) the fire is then turned out of the pit, the object placed there, and stones, fire, and earth heaped over it. This method of cooking is very cleanly, and partakes of boiling and baking. Fire is speedily obtained by making a drill of a piece of hard wood, placing another against the breast, and drilling against a third, rotten wood being crumbled about the hole drilled in. The hands and handkerchief may be used instead of a drill bow. It may also be obtained by rubbing two sticks crossways.

The security of flour in balls has been before alluded to. This may frequently be put into practice where boats' crews are wrecked in the surf, and cannot otherwise obtain food. Flour will always resist water. Farmers throw a bag of flour into a pond to keep it *cool:* the outer edge only forms into paste, about half an inch in thickness. The American whalers put their flour-casks overboard into salt water, to prevent the weevil getting into them. The paste thus formed, hardens into a flinty substance, which resists their attacks. And, lastly, I speak from experience, for ten days the flour-balls, which came from our wreck, with rum and salmon, (the latter obtained sparingly from the natives,) were our only means of subsistence. Knowing the peculiar quality of flour in taking care of itself, the dirty-looking balls, studded like plum-puddings, (with gravel,) were carefully collected and preserved, and opening them, as required, the dry flour in the interior was formed into cakes. Even that wet by salt water was not unpalatable, when the gravel could be extracted. Fresh water may be expected at the foot of a palm-tree; the juice of the palm is wholesome, and, fermented, furnishes wine; its cabbage is nutritious, its leaves furnish tinder, and hats. Convenient shelter for the legs may be afforded by tying the ends of the leaves together, on the fringe system, and winding it round the waist. Many of the fuci are eatable, and may assist in supporting life. Snails of large size are greatly esteemed by the Africans.

Water may be boiled in a cloth, by rubbing the cloth previously on both sides with paste of flour and water. If butter be at hand it will assist.

NATURAL HISTORY.

One of the most important extra duties which attaches to the surveyor's department, is the collection of objects of Natural History, as well as following out the hints which may from time to time be forwarded by any of the scientific societies. He may be sent to explore countries where there is but little chance of his being followed in his day; and it is of the utmost importance to science, the character of his country, and more particularly his own, and those who selected him, that some decided system of collecting, investigating, noting his observations, and, not the least important, labelling his specimens, should be adhered to; in order that the full value arising from his labours should accrue to the country. A book should be devoted solely to this purpose, and, to prevent mistakes, it is not a bad method to denote the specimens of the first port, A; the next, a; and the third, *a;* and thus on through the course of the three alphabets, attaching the numbers to them also.

A collection of valuable hints, for the guidance of officers, has been drawn up by W. J. Broderip, Esq., F.R.S. and late Vice-President of the Geological Society of London, &c., to which the reader is referred for minute details. They are printed for the use of the service, and already supplied to many of our ships.

A few short remarks from a practical collector may not, however, prove uninteresting. Those who enter warmly, or rather *keenly*, into such occupations, do not in general trust the preservation, or cleaning of their specimens, in other hands than their own; and as the surveyor may not have time, for days perhaps, to attend to the main body of his collection, it is requisite to provide for such cases. He should have three small tubs, or japanned tins, capable of containing from one to three gallons, or, he may have a nest of five, from one to five gallons. The instant the specimens from the trawl or dredge are collected, place them in the same water they were taken from, (if possible, in a large glass globe,) and then note their peculiarities whilst they are alive. Never put dead objects with the living. Next; let those which are to be introduced into spirit be put into *tepid* fresh water, and allow them to die, which the temperature of 96° will immediately effect. If time cannot be

spared, about one-fifth of spirit will preserve them for some days. It is advisable to remove them into fresh dilute spirit of the above strength, at least three times before they are finally put into bottles, and then one-third proof spirit or alcohol, will preserve them better than stronger, and the colours will be less liable to change. About one drop of muriatic acid on the top of an ounce phial, *after it is filled*, assists in preserving the colour. This is for small marine objects.

Shells require more attention. The fish may be killed by pouring water at 180° on them, and repeating it three times. After this, plunge them in the coldest water you have, and the fish will come away. The voluta are very liable to become discoloured, and lose their enamel; but this may be obviated by putting them in a tub of sand, the bottom of which should admit of the fluid escaping, through canvas. They should have a layer of four inches of sand between them and the bottom. Pour boiling water over the sand occasionally, and in a week or ten days they will be found free, when they may be well washed in cold water, and stuck on their ends for some days in dry sand. The murex is very troublesome, as well as the cyprœa, and may be similarly treated. *Boiling* water is apt to injure the shell, and particularly the hinge cartilage of bivalves.

Bivalves should be made to open by pouring water at 180° over them, and the instant they gape, the muscle separated by a knife or spatula, and the shell removed into fresh cold water. The fish being cleanly removed, they should be carefully closed, (taking *great care* that no dirt lies in the hinge, which may break the teeth,) and securely tied in this position. To the surveyor, whose time is so multifariously engaged, it is requisite to have drawers fitted to receive his collection, and where they can remain unmolested until he has time to pack them in cases. Others can readily prepare labels under his directions, and he can *direct* those of least importance to be rolled up in them, taking care that the depth, the temperature at that depth, the nature of the bottom, latitude, longitude, &c., be duly noted with the respective numbers and remarks. Fuci should be well washed in fresh water several times, dried in the *shade*, and preserved between brown paper, which retains less moisture than any other, (and for this reason, is selected by the manufacturers of steel articles.)

In collecting birds, it is advisable to skin them within as short a period of their death as possible. If on detached service, and the

materials not at hand, or time not to be spared, it may be advisable to immerse them in spirit; but they should be opened and drawn, the interior filled with tow, and the legs and wings wound round with thread, to keep them from spreading and deranging the feathers. In the case of large animals, the skin may be brought away, and a solution of rum and soap, well rubbed in, will be found to stop decomposition, if kept freely exposed, and not allowed to fold, (or one moist part touch another.) The bones should be preserved if possible; and as they are likely to become offensive, the simplest method of preserving them, and obviating the disagreeable effluvia, is to head them up in a cask, and fill it with wood ashes.

In preserving minute objects, glass tubes, of various diameter, will be found very convenient. Cut slips of cork to the diameter, and notch them to admit of the spirit flowing past. Introduce an object, force the cork disk down, to barely admit it to occupy its own length. Introduce another object, then the cork disk, &c. By this method, each object is kept clear of the next, the fluid can be removed when turbid, and fresh introduced, and the objects are always in a more convenient state for examination than when huddled together in a large bottle. [I have practised this method since 1821, and found it very convenient.]

It is very difficult to preserve the colours of fish, echini, asteriæ, &c.; but after being well washed in fresh water, and the intestines withdrawn, they should be anointed with spirits of turpentine, and afterwards immersed in a saturated solution of camphor and spirit. After one or two exposures, the camphor having each time evaporated, they may be either immersed in spirit or dried.

The interior of asteriæ should be closely, and very carefully examined for minute shells, and where heaps of them are to be collected on the sea shores, they should be taken on board, and cut up to search more effectually. The stomachs of fish frequently contain perfect minute and rare shells. Volutæ will take bait; and many others, as well as bivalves, may be taken by the trot. A canvas-bag, made in the shape of a jelly-bag, stuffed with straw, and meat introduced in the small end, will entice shell-fish. It should be raised by the large end. Frequently a hide is found unfit for service, and condemned to be thrown overboard. *Roll* this up, tie it, and attach a weight to one end; a loose line being passed through the opposite, it may thus be closed when required to be hauled up.

In tropical climates, ships soon become infested with ants and

other vermin, which render birds and skins difficult to be preserved. The surest method is to roll them up separately in paper, containing camphor, as well as a little loose preserving powder; paste the edges all round. When dry, give it a complete coat of arsenical soap. Over this, (when dry,) paste some thin paper, and stow them *over-head* in the cabin, until enough are collected to fill a case. The cases should be sewed up in canvas, and have two or three coats of blacking, (coal tar,) which not only keeps the vermin away, but renders them impervious to moisture, (by which the *labels are obliterated.*)

With respect to geological collections, the directions furnished by the Geological Society are also supplied through the Admiralty, which will be introduced here, with such further remarks as the nature of our service may seem to call for.

First. The chief objects of research are, specimens of rocks, marls, or clays, which contain shells, plants, or any sort of petrifaction.

2. The petrifactions should, *if possible*, be kept united with the rock, sand, or clay, in which they are found, and not detached, unless they are in the face of a cliff, and cannot otherwise be obtained. Should the shell be in a loose matrix, both should be carefully preserved.

3. If several varieties of stone are found in the same cliff, or quarry, and particularly if they contain petrifactions, specimens of each should be numbered in their order of succession; commencing with the upper, and noting, by eye, if actual measurement cannot be had, the thickness, dip, and direction of the beds. Three inches square, by one and a-half thick, is a convenient size.

4. If the rocks are stratified, state their inclination, &c., or if twisted. Make a sketch, and insert the lines of stratification, taking care to note the direction of the dip; and, if possible, if it dip *from* or *towards* you, as the face of the cliff may prove a transverse section.

5. One kind of rock may cut through the bed of another. Note whether the beds are in the same plane on each side of the intruding rock; if not, note the extent of the disturbance, and if a difference can be traced, where the two kinds of rock are in contact; specimens of each, at these points of contact, should be collected, and the position noted on the sketch.

6. If wells occur, obtain the list of the beds passed through in

digging them, noting their order and thickness, numbering from the surface downwards; the water, if peculiar, should be preserved.

7. In volcanic districts, procure a list of the volcanoes now, or recently, in action, and of those extinct, noting their position on the chart, their distances from sea, lakes, &c.; the extent, nature, and, if possible, the age of particular streams of lava, or the relative ages of different streams: whether the lava currents conform to the valleys, or are seen at different heights above the present rivers; and also if any gravel-beds be discovered beneath the streams of lava.

8. It will be sufficient to *note* where coal, bitumen, salt, alabaster, metallic ores, or valuable minerals are found, and the rocks in which they occur; but specimens of the rock, and of the coal, if not known as a coal district, should be obtained, particularly if plants have been found; it may then be advisable to procure minute data, specimens of the various strata, and ascertain if limestone, iron ore, or springs of bitumen, exist near the coal. If the limestone contain shells, obtain all the varieties to be had. Ascertain the value of the pit, &c., and if the coal be adapted for the forge, or supplies for steam vessels. Note whether pyrites abound in it.

9. Make diligent inquiry amongst the workmen, natives, &c., if, in their operations in gravel-pits, clay, mud, or sand, &c., they meet with bones of any kind, shells, &c., and if to be procured, preserve them carefully, noting strictly how far beneath the surface; the chances of their being so situated by the act of man, or nature. Inquire particularly for teeth, vertebræ, &c., which not unfrequently are used as ornaments by savage tribes. Some little *caution* in this case is *necessary* to obtain the truth. It must be gained indirectly, as they frequently place great value on them.

10. The examination of caves, clefts, &c., should not be neglected. The lowest pits are most likely to contain bones. If the solid rock be covered with a crust of spar or marl, break through, and examine for bones, horns, or pebbles.

11. Should the surface of the country present straggling blocks of stone, note if they be angular or rounded, if they appear to have been rolled, and whether they differ from the stratum on which they rest. If so, endeavour to trace them to their native bed. Note the heights at which gravel occurs, and if it be composed of the debris of the adjoining rocks.

12. At dead low water on the springs, examine rocks and clay

for fossils. The clay should be worked into with the pickaxe, and the rocks, if they can be removed, rolled up above high-water mark, to be examined at leisure. Live shells will frequently be found by these means, particularly pholades, lithodomi, &c.

In detaching specimens, obtain the *interior* of the *cliff*, or abounding rock, not the loose rounded masses on the beach. If the sand on the beach shew black spots, collect a little, and agitate it in a tube with water; the black will thus collect on the surface, and may be tested to ascertain if it contain magnetic iron sand, &c. Where shoals in the mouths of rivers dry at low water, as well as on those higher up, the nature of the sand should be examined and collected, particularly if the river be little known, and bottles of water, in its most turbid state, should be preserved.

A reduced outline of the chart should be made, and the features represented by colour, with letters, or numbers of reference, inserted; and a description, such as the collector *himself* is impressed with, should be drawn out. Whether he understand the principles of geology or not, his *remarks* and the *specimens* must be the standard from which just conclusions are to be drawn. Once duly recorded, their merit can readily be appreciated, and no feeling of incompetency should prevent him from doing his *best*. The ungenerous sneer will never come from a man of talent.

In adopting colours, those which the eye classes as nearly meeting that of the rocks themselves are preferable, and more familiar to the collector.

The height to which the sea rises, and to which it may have risen by hurricane, or subterranean agency, should be particularly noted. [*All sections should be to low-water springs.*]

Faults, or where the section represents a stratum abruptly displaced, should be minutely measured, to ascertain if it arise from a slip, (in which case the edges would coincide in measurement,) or has been forcibly imposed, or pressed into contact. If this measurement be accurately taken, (in the event of the space being filled with earth or foreign matter,) conclusions can be drawn as to whether it arose from earthquake, or other agency.

It is sometimes next to impossible to determine if the strata which are exhibited on the face of a cliff, dip from, or towards. A little minute investigation after rains will show if the water be taken *up*, or given *out*, by the lines of stratification, in which case a fair inference may be drawn as to an ascending or descending plane. Bone beds,

particularly in high latitudes, may almost be scented, from the strong effluvia of burnt horn and sulphurous exhalations; the mud is generally slimy and peaty.

In drawing sections, care must be taken to distinguish between masses which have simply slipped and fallen away, and the real cliff itself. Each specimen should be marked with pencil on the spot, or placed in a basket in such order that no mistake can arise. The most secure method is white or black paint. Each specimen should have a label tied to it, and be carefully packed in strong brown paper. One heavy hammer; one lighter, for trimming; an iron lever, or spudgel; and several cold chisels; one heavy, with four-sided point, stout enough to be used with a maul, will be found convenient, either in seeking shells or rending rocks, (as the finest lithodomi are found in old madrepores, or coral.)

It not unfrequently happens that specimens are too ragged, or rough, at their surfaces, to take a number. A plan once adopted, for the sake of experiment, and to which I have contemplated giving publicity, enables the traveller to effectually mark his specimens on the spot, and the fluid used dries almost instantly. Provide two ounce phials, and have them fitted in tin cases, so that in the event of their breaking the neck alone will keep the contents safe. Introduce in each a varnish of black and red sealing-wax, dissolved in alcohol; a sable brush should accompany them.

This enables the collector to number, letter, or mark instantly. Should the surface be ragged, he may note thus—

Ragged; large, *red* = ∘ No. = 1 small black dot ⸰ No. 2 .∘. No. 3 .∘. No. 4 . ∘ . No. 5 . ∘ . No. 6 ·∘· No. 7 ∘ · : No. 8 ∘ . : . No. 9 ∘ · ⁝ · No. 10 ∘ ∘ No. 11 ∘ . ∘

The *black large dot* may then precede, or the red may be repeated for tens. If any of these distinct forms are *noted*, they are as intelligible as the most perfect form of figure, or letter.

The advantage of dots is this. They can be placed in *hollows*, which will prevent their liability to chafe.

The advantage of sealing-wax thus applied is, that it will resist moisture, which is material, as heavy cases of stones are generally placed in the hold. [In the Blossom the water got to them, and destroyed the labels, which caused me to turn my attention to this point.]

As the specimens can be of little value to a private collector, and of the greatest to the public, they should be forwarded to the Geolo-

gical Society, where they will be examined and described. It may be necessary to add, that if directed to "W. Lonsdale, Esq., Curator, Geological Society of London, Somerset House," they will be duly acknowledged. The notes should also be forwarded.

Description of Beacons made use of in the Survey of the Western Coast of Africa.

A cask of 32 gallons (latterly 60) is furnished with doubled staves, and of greater width at bung and opposite, as well as double heads. Holes are bored through the bung and opposite staves to admit of the passage of a spar of 3½ in. diameter.

This spar, previously well parcelled and tarred, is driven firmly home, cleated, to prevent its working out, and caulked round the cleating. Three feet project on the larger end, and nine feet on the smaller. The larger end is furnished with irons for a topmast which is 22 feet in length.

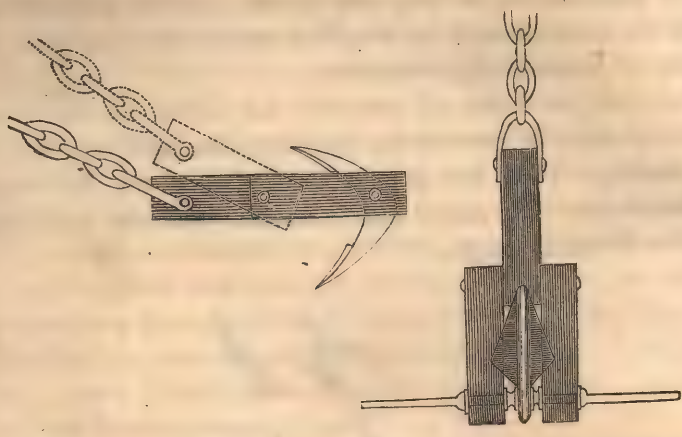
Close to the cask, at *b*, a thimble is secured, through which the mooring cable passes, as well as one similar beneath at *d*, where the cable is clove-hitched, parcelled, and its parts seized to the spar to prevent chafe. At *c*, ballast equal to 2 cwt. is attached, at three fathoms below the cask.

They were *moored* taut in the line of stream, had latterly full-sized buntin flags, and were found to stand bad weather well, and maintain an *erect* position in very strong currents and tides.

Description of Mooring Anchors for Beacons, &c.

In the Nautical Magazine, No. XI., the description of the following make-shift anchor, or mooring for beacons, is described.

It is formed of three pigs of ballast, each weighing 56 lbs. and a pair of moveable flukes; the bar connecting these with the ballast, serving also as the stock of the anchor. The dotted line in the sketch shows the position of the single pig, when there is a strain on it.



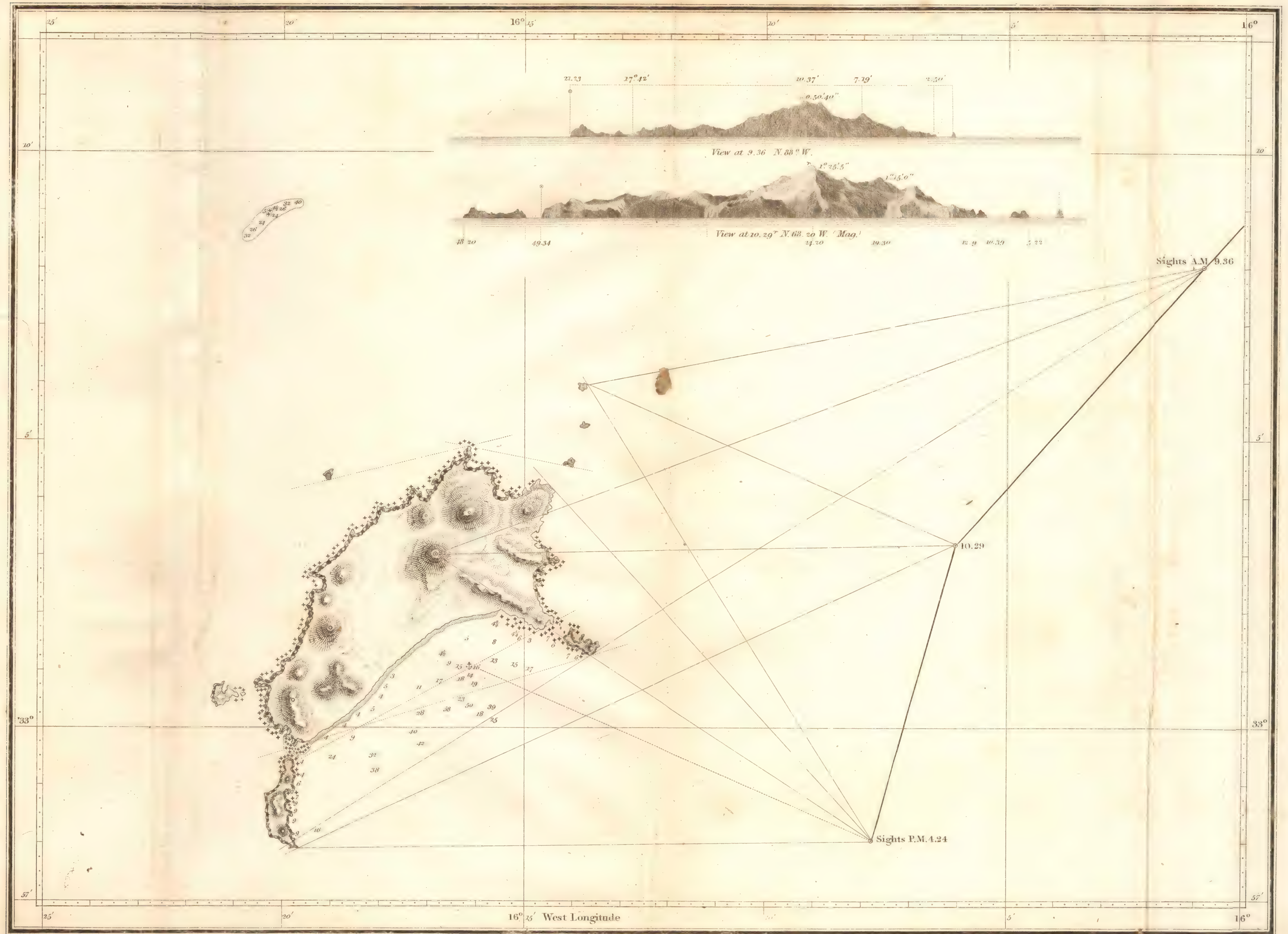
The whole weight of the 3 pigs, each being 56 lbs. would be 168 lbs.; and allowing 22 lbs. for the weight of the extra iron used, would give a total weight of 190 lbs.

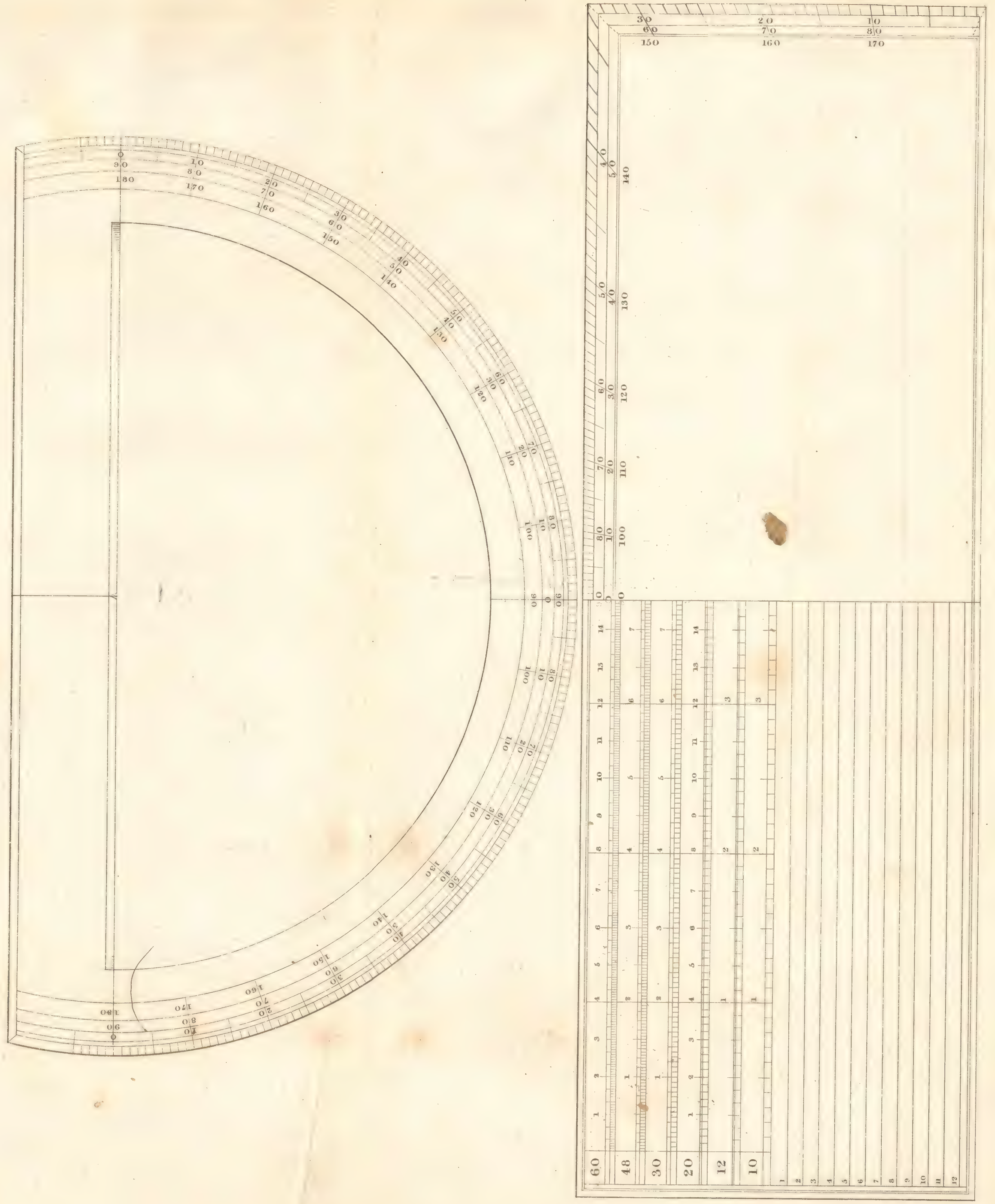
This anchor was constructed on board the Etna. Its convenience, in point of stowage, is great; and it is more easily handled than those of less weight. They were principally constructed for the beacons, and were found to hold well; they never came home—others failed, and were in consequence lost, with the beacons.

It is only necessary to carry spare flukes and stocks to sea, and they can be formed to any weight, by the repetition of pigs of ballast, or a series backing each other. Four such, would stand as great a strain as a 7, or perhaps 10 cwt. anchor, and could be readily laid out by a gig, being only equal to the weight of five extra men.

LONDON:

IBOTSON AND PALMER, PRINTERS, SAVOY STREET, STRAND.





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London Published by Pelham Richardson, Cornhill Nov. 1st 1834.

GEOMETRICAL DIAGRAMS

Fig. 1.

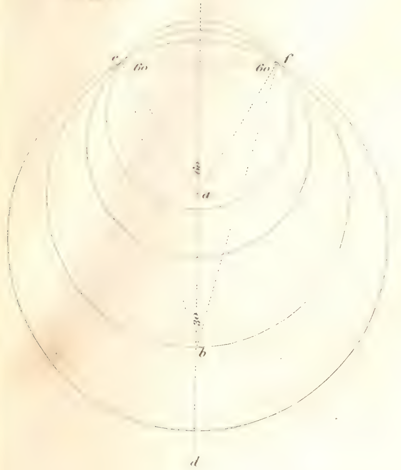
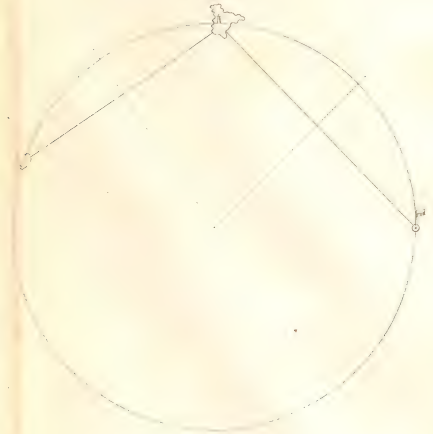


Fig. 2.



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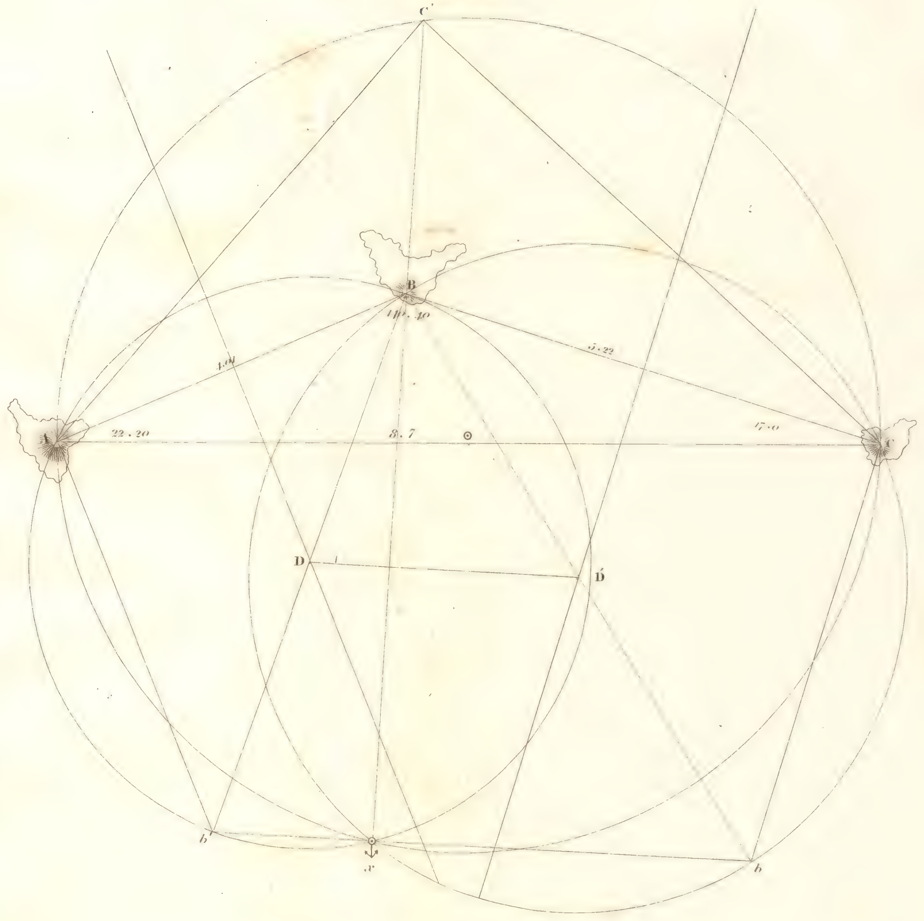

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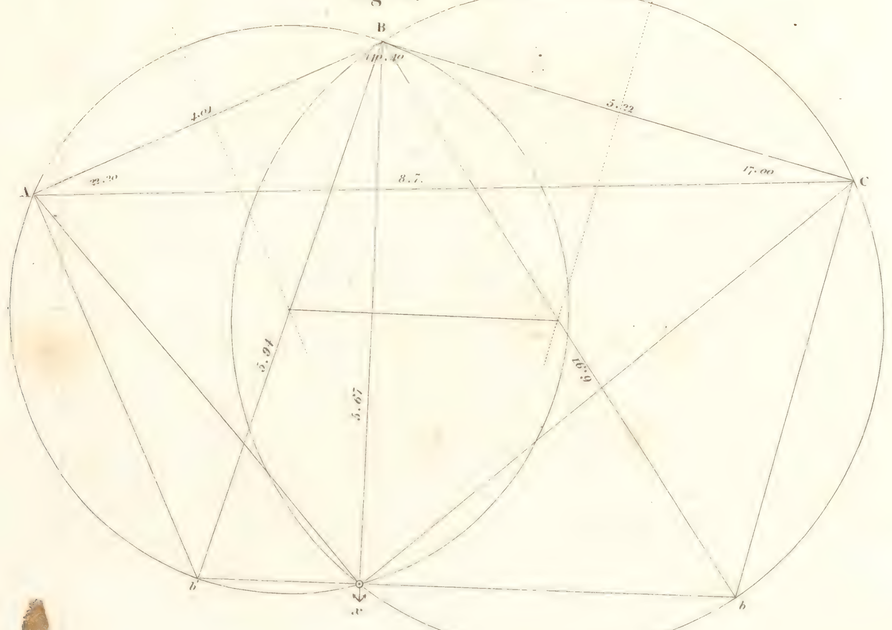

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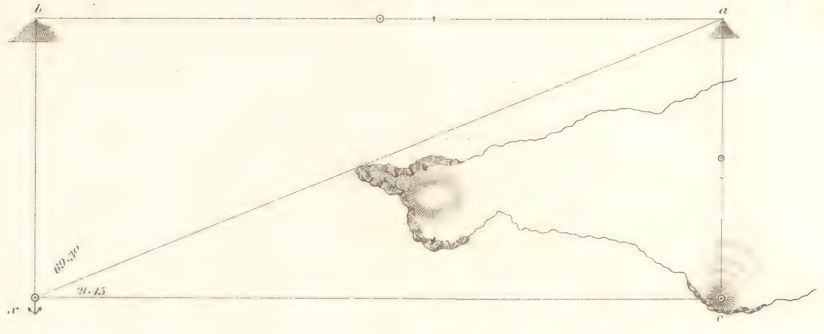

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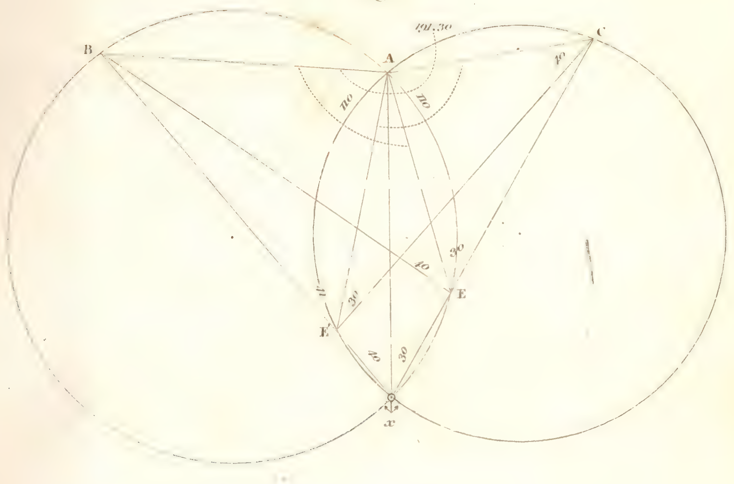
GEOMETRICAL DIAGRAMS

Fig. 6.



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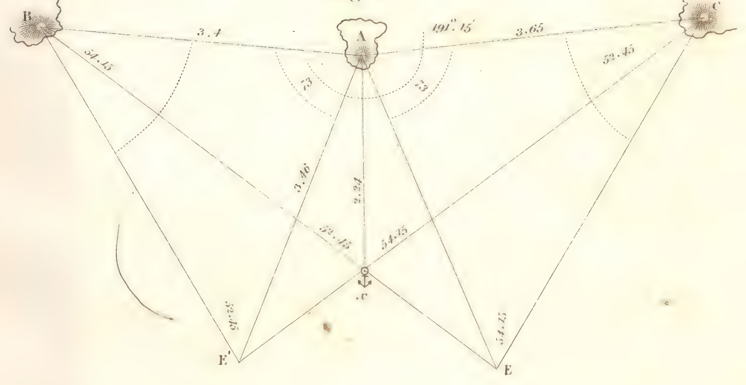

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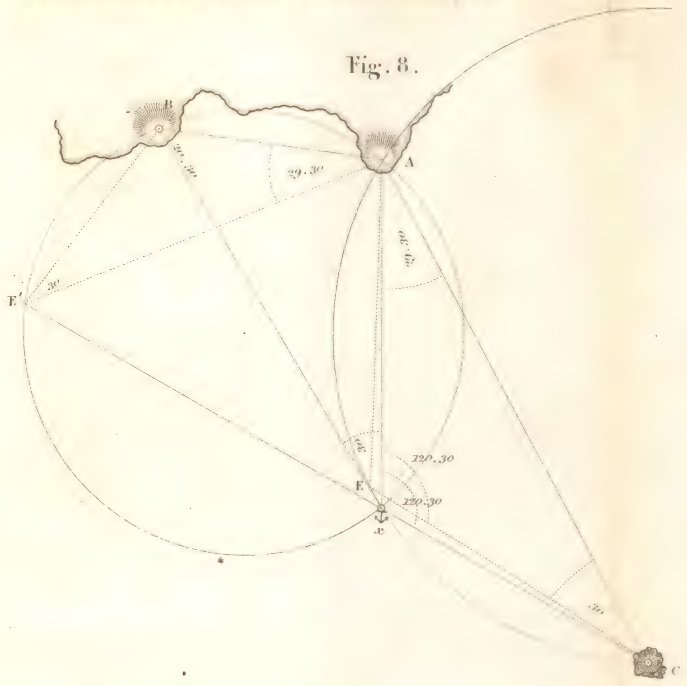

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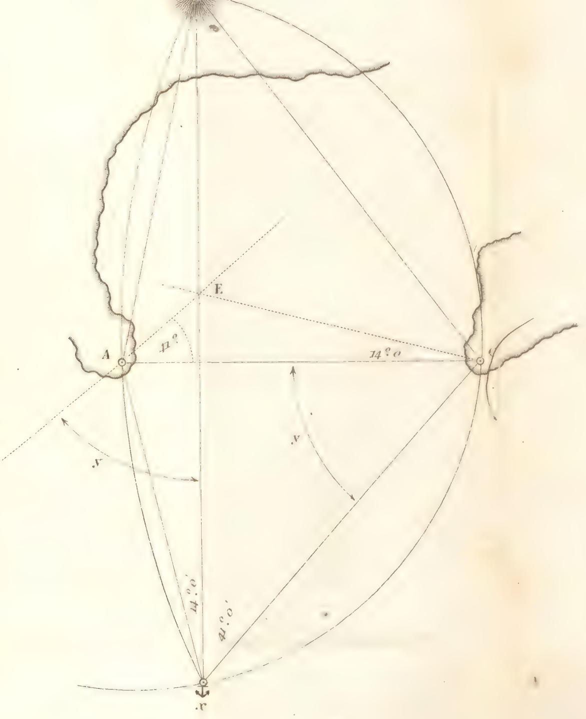
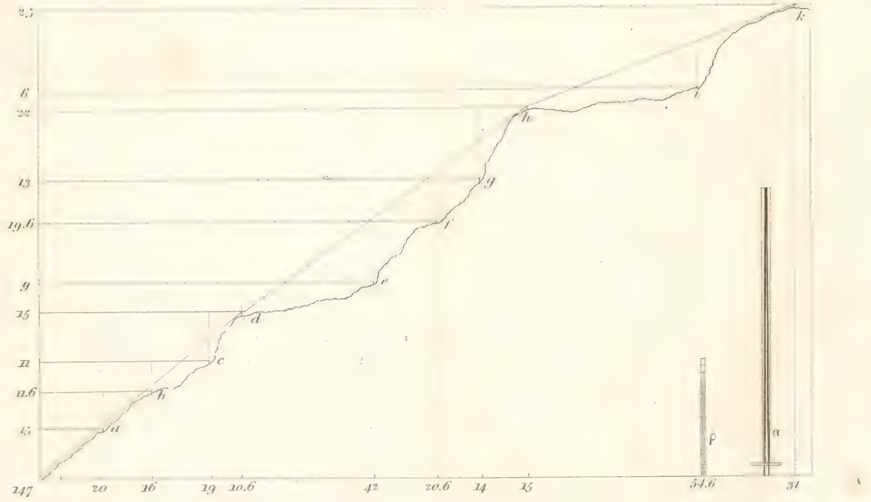
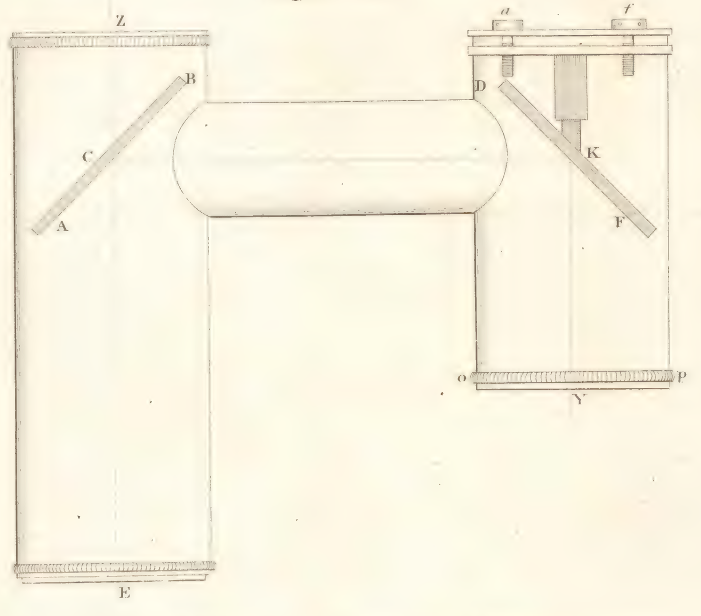


Levelling Fig. 10.



Rapers Ins^t.



AB *Mirror in the lower half of tube* E.Z

D.F *D° plane at right angles to* AB

a.f adjusting screws to mirror D.F

E. *Eye end of telescope.*

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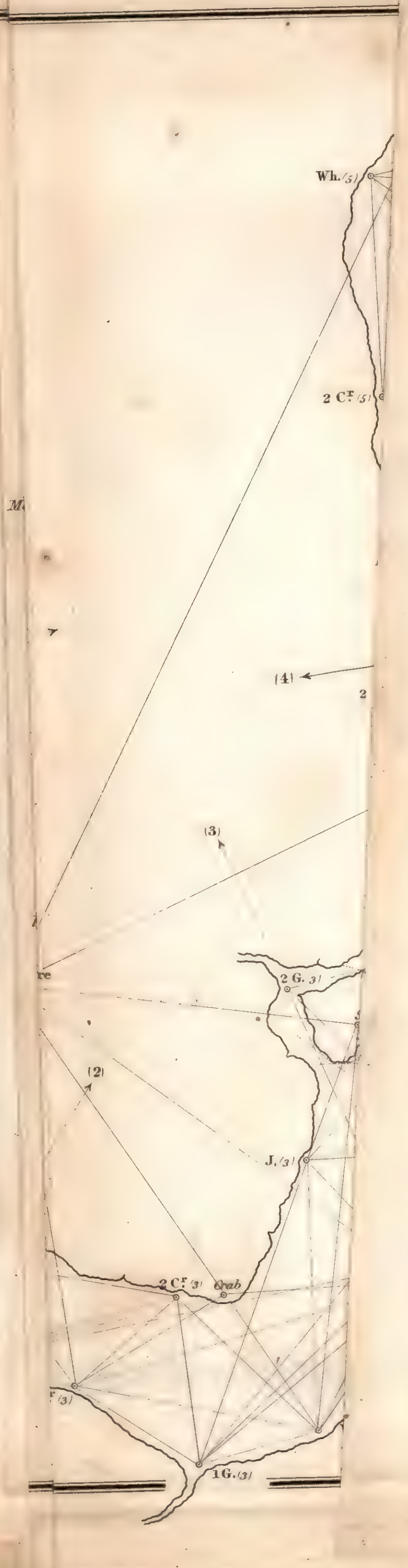
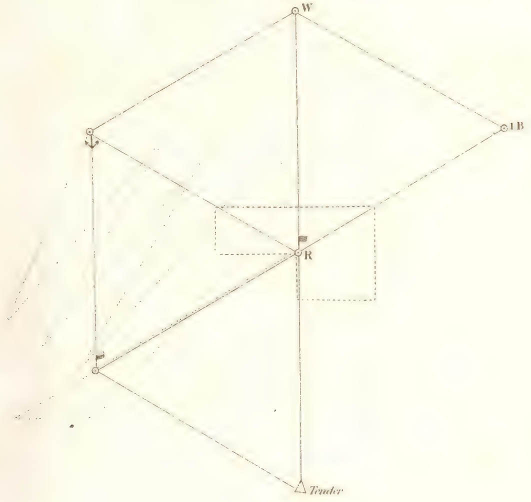
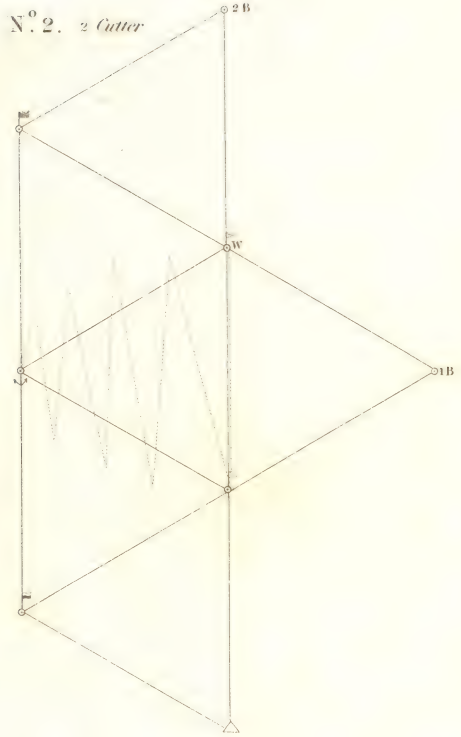

Wh. (5)
2 Cr (5)
(4)
(3)
re
2 G. (3)
(2)
J. (3)
2 Cr (3)
Crab
r (3)
1 G. (3)

DIAGRAMS FOR BOATS ORDERS

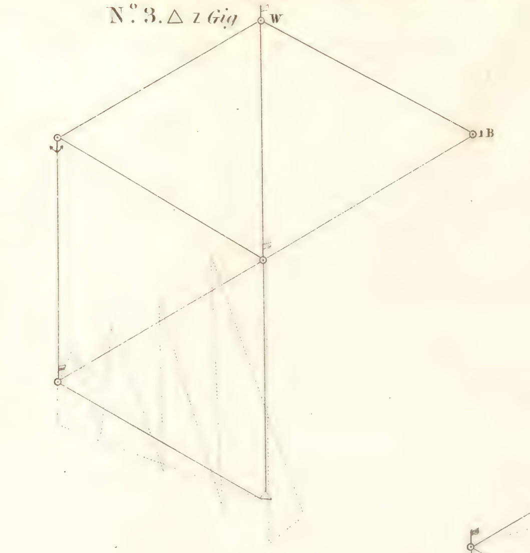
N.o 1. 1st Cutter



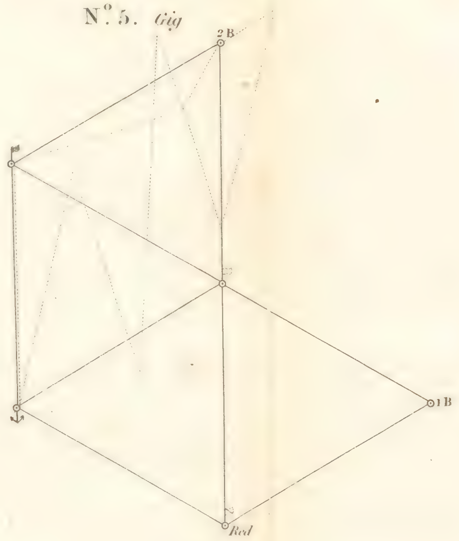
N.o 2. 2 Cutter



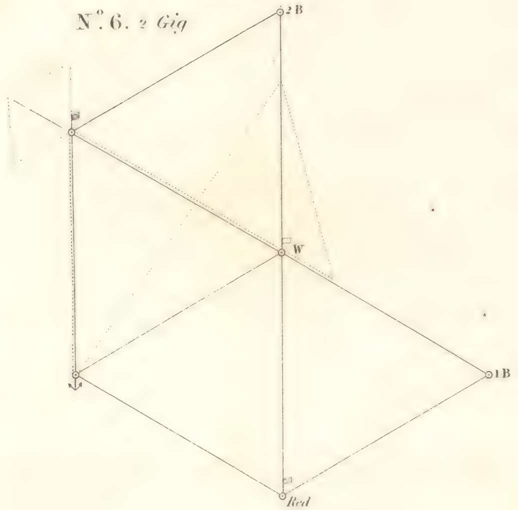
N.o 3. △ 1 Gig



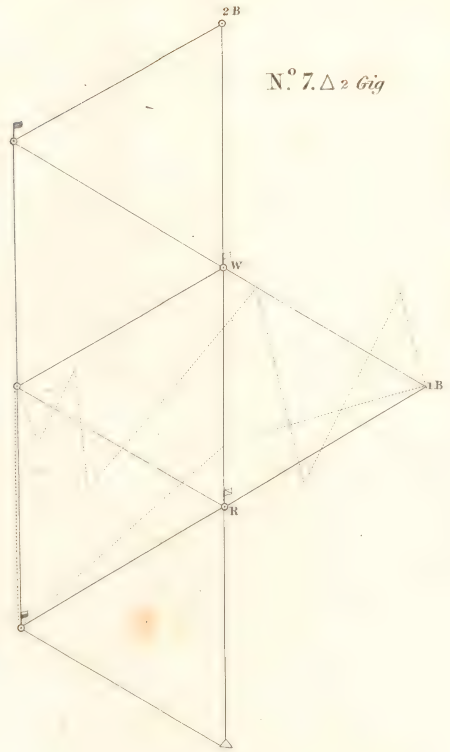
N.o 5. Gig



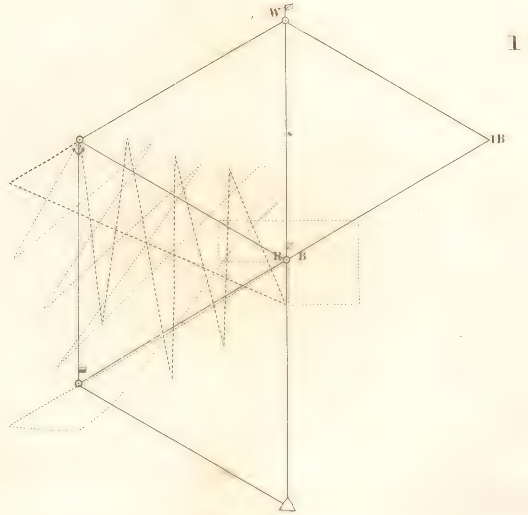
N.o 6. 2 Gig



N.o 7. △ 2 Gig



1 C.r ○ (2 day.)



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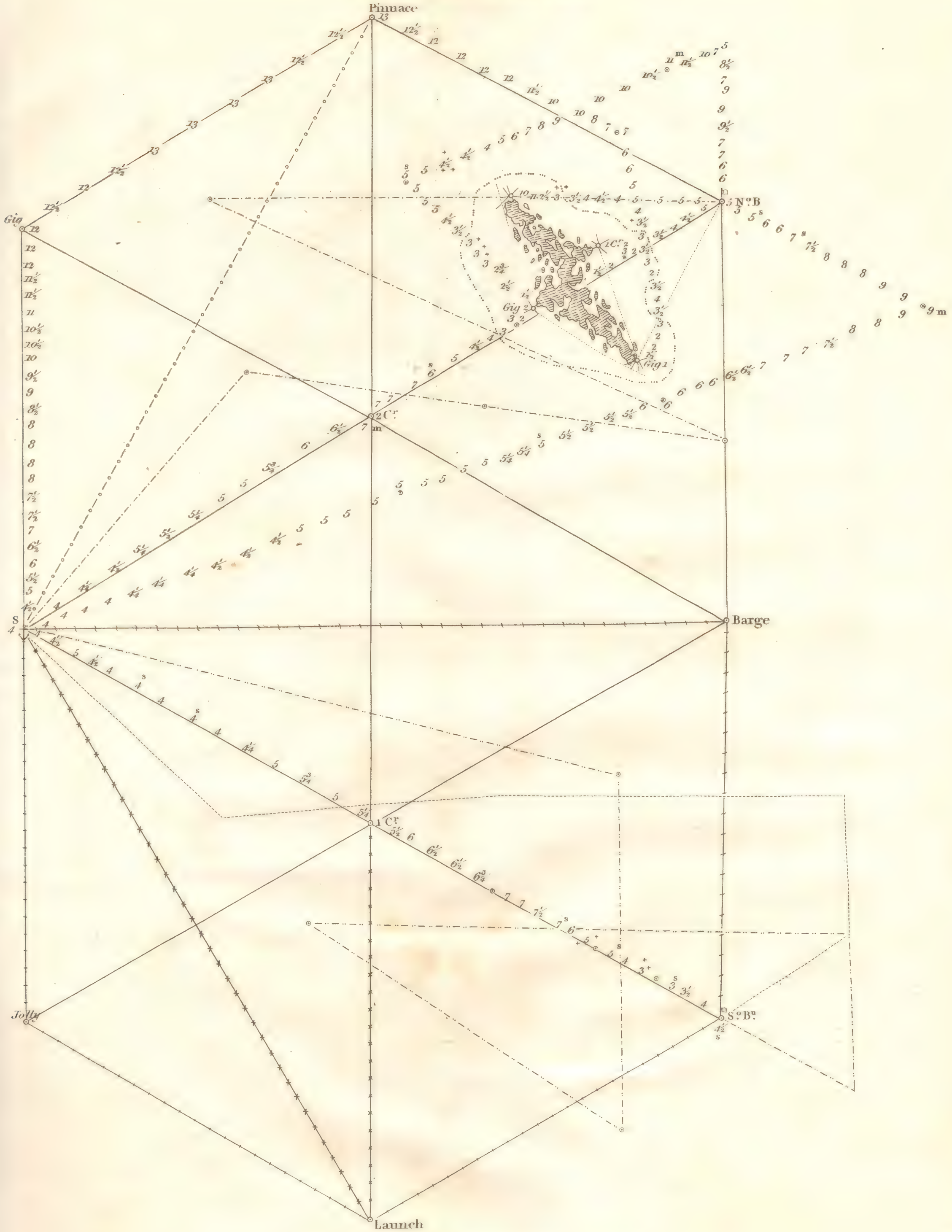
FRIGATE SURVEY



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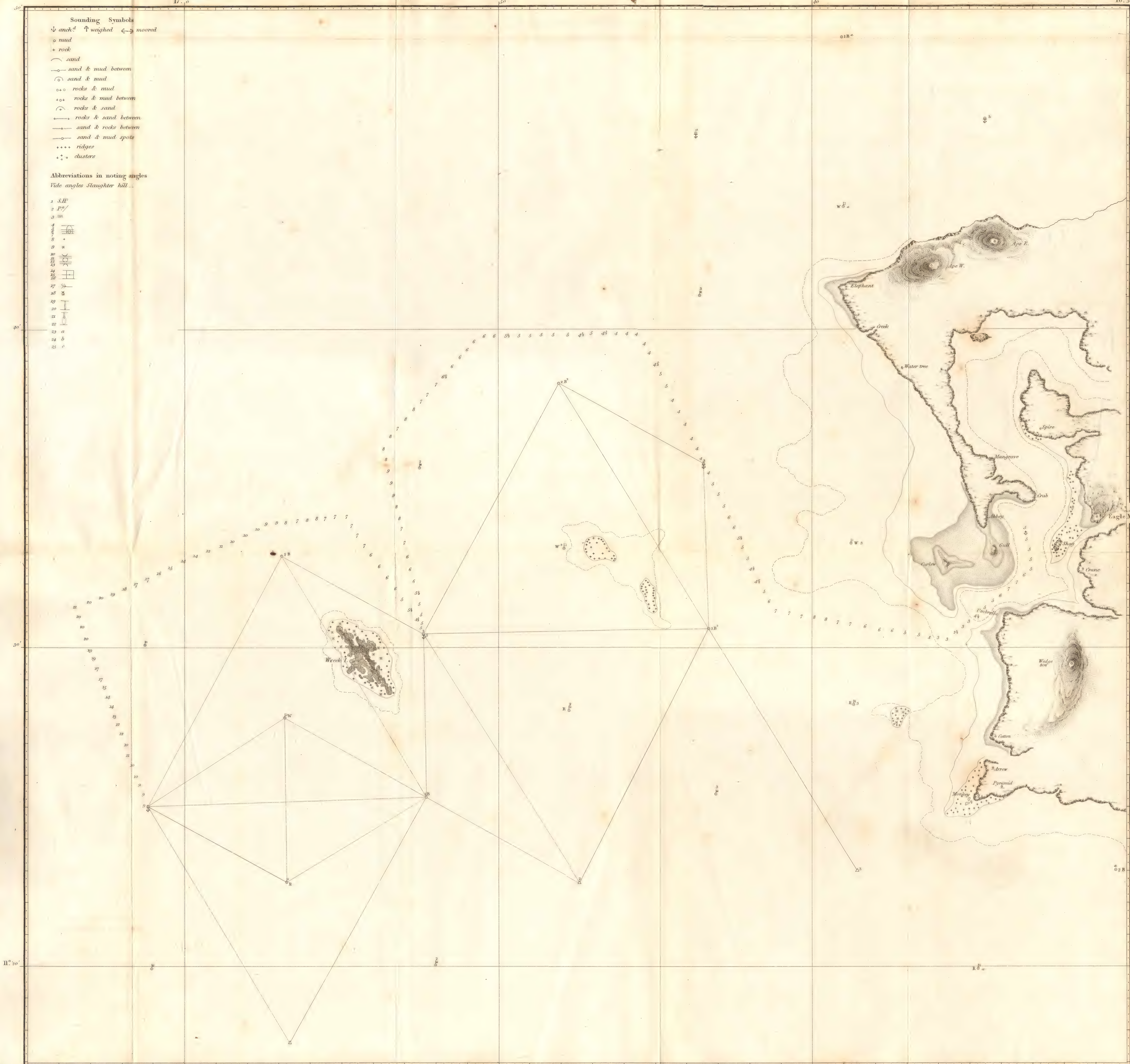

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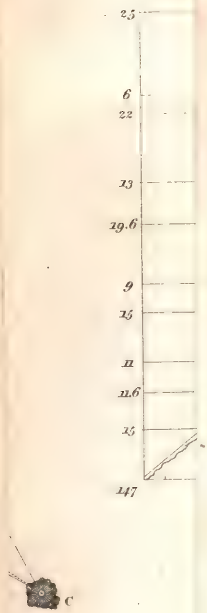
25
6
22
13
19.6
9
15
11
11.6
15
147
C

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Fig.1

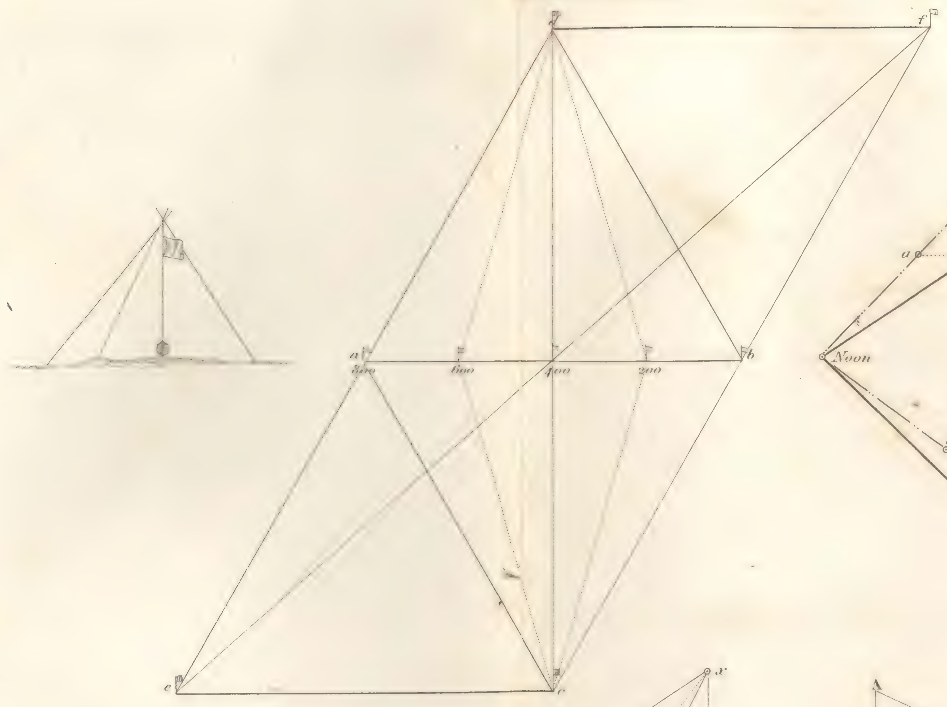

Fig.3

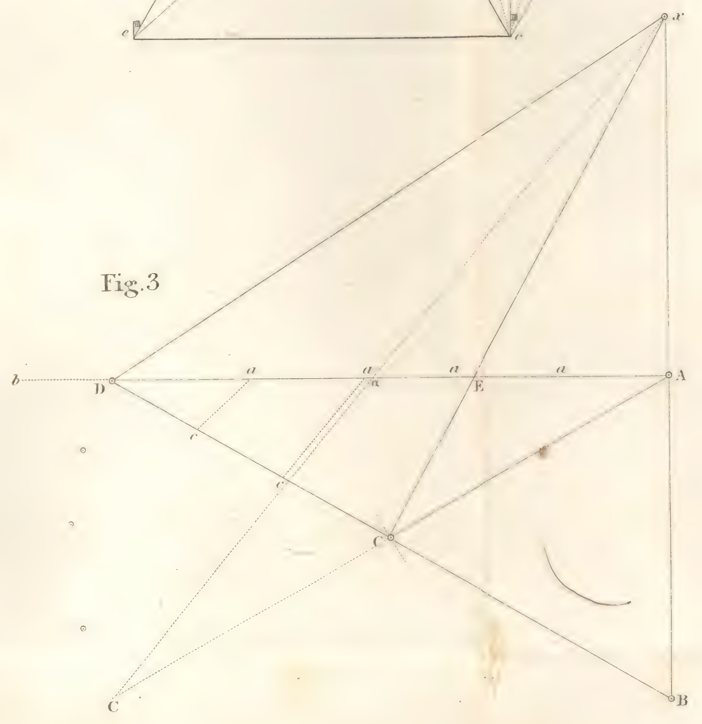

Fig.4

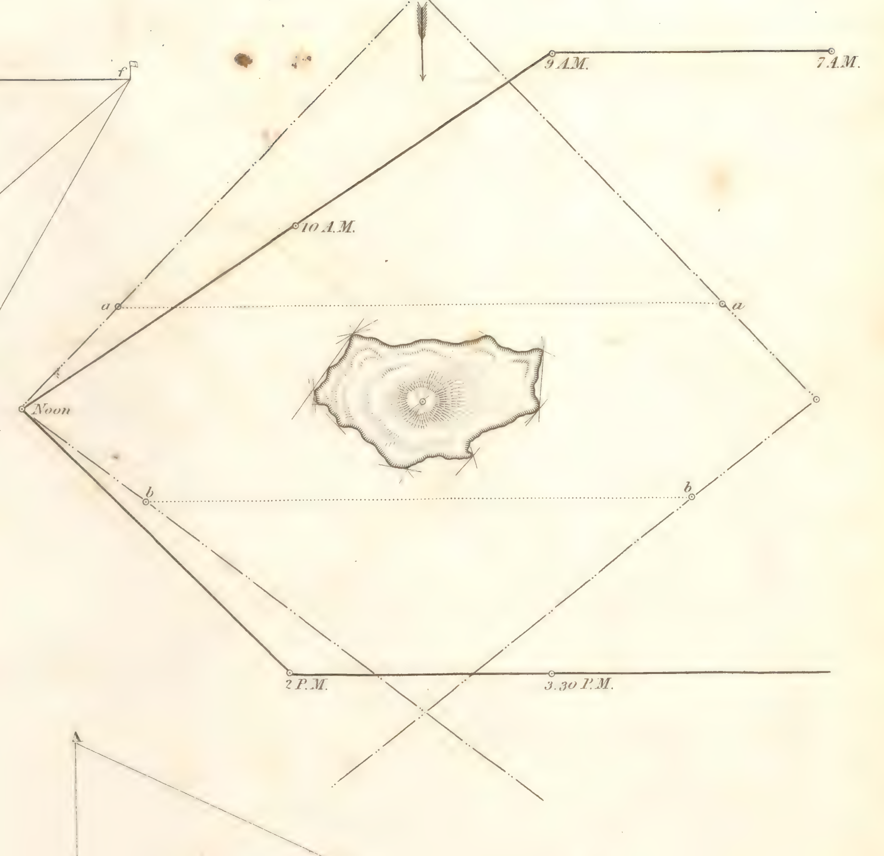

Fig.5

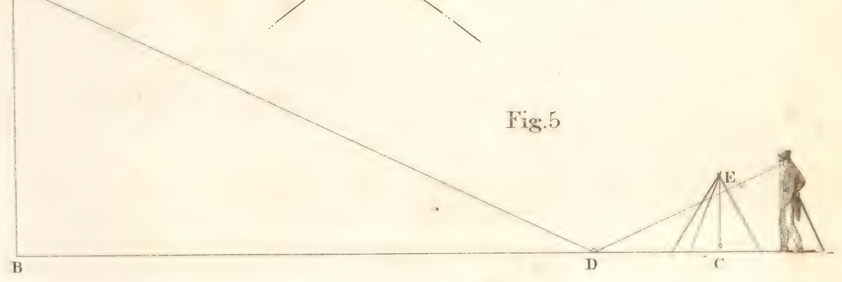

Fig.6

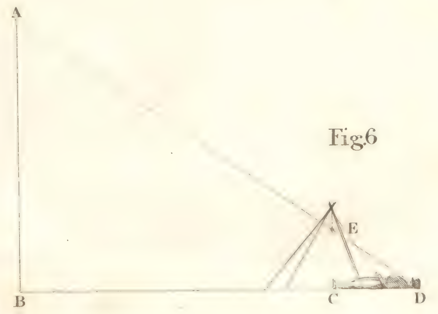

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Fig. 1.

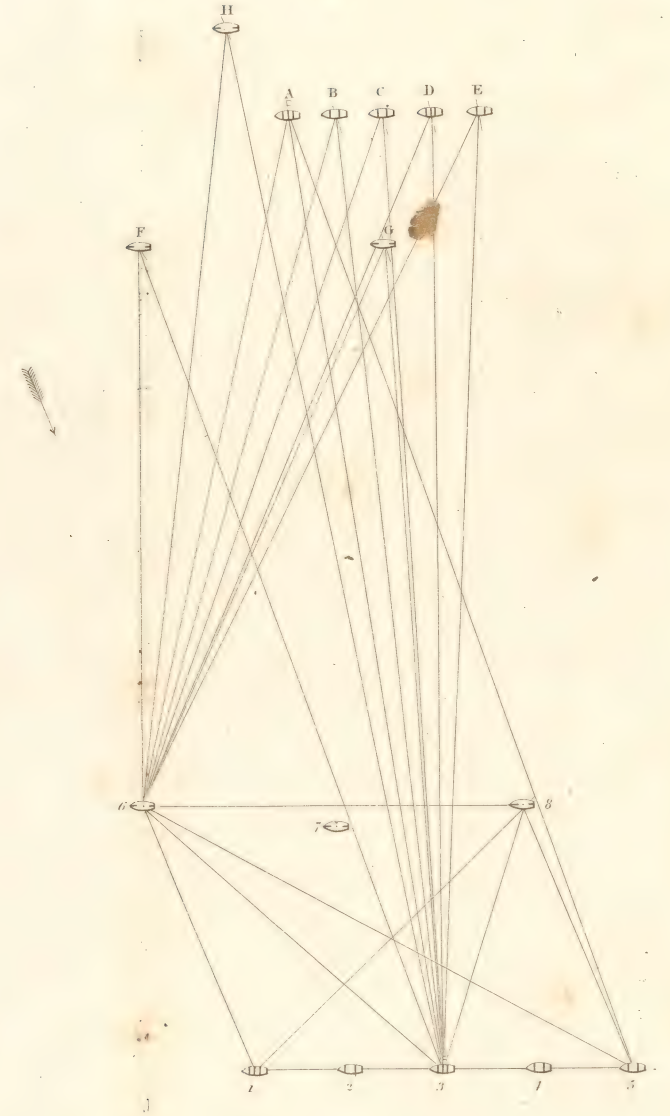


Fig. 2.

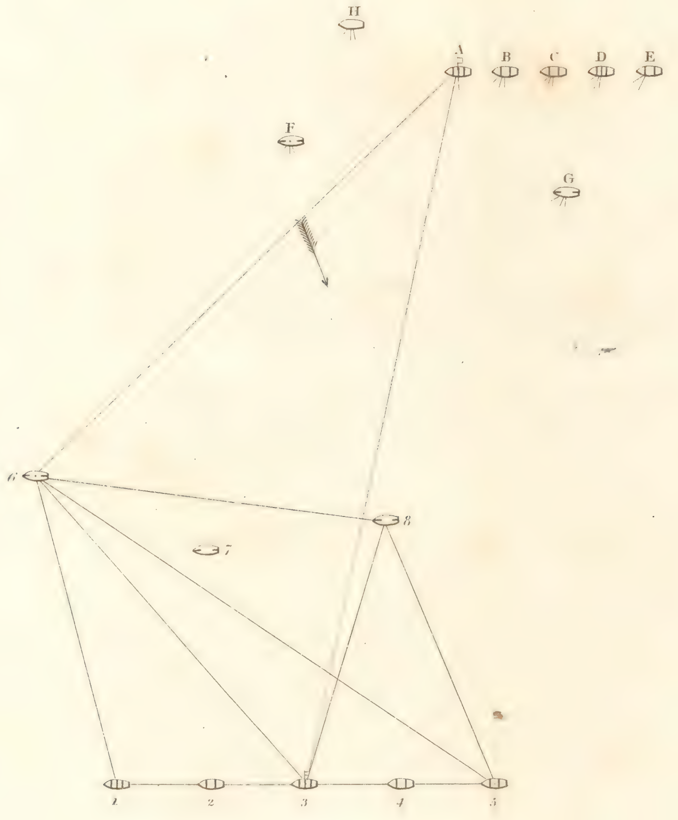
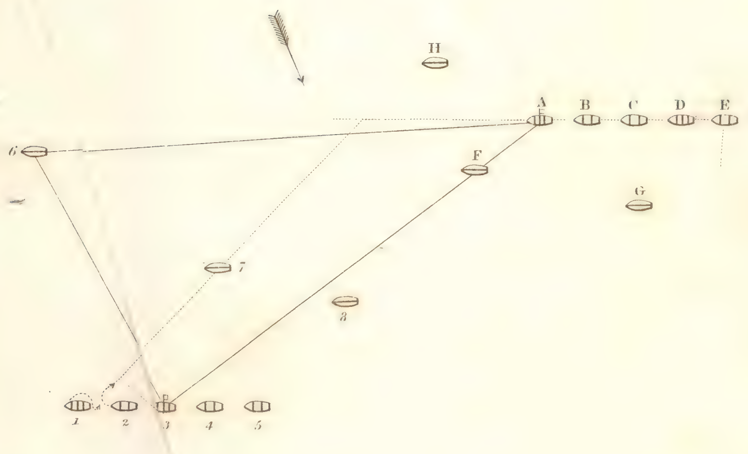


Fig. 3.



Scale of Miles.

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BELCHER'S
NAUTICAL
SURVEYOR